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# FRONTISPIECE
## TO THE
# PRACTICAL BUILDER.

THE HOUSE OF FULTON ALEXANDER ESQ.[E]

*at Patrick near Glasgow.*

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# THE NEW PRACTICAL BUILDER,

AND

# Workman's Companion:

CONTAINING

A FULL DISPLAY AND ELUCIDATION

Of the most recent and skilful Methods, pursued by

*ARCHITECTS AND ARTIFICERS,*

IN THE VARIOUS DEPARTMENTS OF

| | | |
|---|---|---|
| CARPENTRY, | MASONRY, | PAINTING, |
| JOINERY, | SLATING, | GLAZING, |
| BRICKLAYING, | PLUMBING, | PLASTERING, &c. &c. |

INCLUDING, ALSO,

NEW TREATISES

ON

GEOMETRY, THEORETICAL AND PRACTICAL, TRIGONOMETRY, CONIC SECTIONS, PERSPECTIVE, SHADOWS, AND ELEVATIONS;

A SUMMARY OF THE ART OF BUILDING;

COPIOUS ACCOUNTS OF BUILDING MATERIALS, STRENGTH OF TIMBER, CEMENTS, &c.;

A DESCRIPTION OF THE TOOLS USED BY THE DIFFERENT WORKMEN;

*AN EXTENSIVE GLOSSARY OF THE TECHNICAL TERMS*

PECULIAR TO EACH DEPARTMENT;

AND

THE THEORY AND PRACTICE

OF THE

**FIVE ORDERS,**

AS EMPLOYED IN DECORATIVE ARCHITECTURE.


BY PETER NICHOLSON, ARCHITECT.


THE WHOLE ILLUSTRATED AND EMBELLISHED WITH NUMEROUS PLATES, FROM ORIGINAL DRAWINGS AND DESIGNS, MADE EXPRESSLY FOR THIS WORK, BY THE AUTHOR, AND CORRECTLY ENGRAVED, UNDER HIS IMMEDIATE INSPECTION, BY MR. W. SYMNS, AND OTHER EMINENT ARTISTS.


LONDON:

PRINTED FOR THOMAS KELLY, 17, PATERNOSTER ROW.

1823.

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# PREFACE.

THE WORK here respectfully submitted to the Public will be found to comprehend the PRESENT PRACTICE OF THE ART OF BUILDING, reduced to PURELY SCIENTIFIC and GEOMETRICAL PRINCIPLES, and yet explained in a manner so simple, as to be easily intelligible to any attentive Reader.

To facilitate this important object, the Author has commenced with a short Treatise on GEOMETRY, theoretical and practical, peculiarly adapted to the general object of the Work, and containing such theorems and problems only as are *absolutely necessary* to be understood by every person connected with the leading departments of the art.

And here the writer cannot refrain from adding a few words, with a view to impress upon the minds of WORKMEN engaged in the construction of buildings, whether CARPENTER, JOINER, MASON, or BRICKLAYER, the PARAMOUNT and UNSPEAKABLE IMPORTANCE of obtaining some knowledge of the PRINCIPLES of GEOMETRY; since, of all the numerous classes, concerned in mechanical arts, THEY require the most intimate acquaintance with this science.

The execution of the design of the architect is generally left to the skill of the workman; who is, of course, presumed to be fully competent to the performance of the task which he undertakes. Now, if he be not practically acquainted with the *geometrical* construction of the object to be executed, he is not only unfit for the undertaking, but, at every step

that he takes, he will manifest his ignorance and inability, and eventually overwhelm himself with confusion and disgrace. While persons of this description draw down upon themselves such merited degradation, those who, by assiduous application, have made themselves masters of the principles of geometry, and have obtained a clear and comprehensive view of the practical application of these principles, will not fail to enjoy that intellectual satisfaction which results from a successful termination of efforts, conducted with scientific skill, and crowned with general approbation; and, at the same time, open for themselves a legitimate path to that reputation which directly and naturally leads to opulence and independence.

The articles on Carpentry and Joinery are treated at great length, as their superior importance demand. Indeed, it has been the chief study of the Author's life to give to these two branches the utmost degree of scientific connection and development of which they are susceptible.

In Masonry, the artist will find an ample detail of the methods of cutting stone, illustrated by several plates, answering to most purposes which present themselves. And since the principles laid down in this Work are every where of a general tendency, the judgement of the workman will enable him to apply them wherever difficulties may occur.

The art of Bricklaying is but little connected with the study of geometrical lines; since the texture of bricks is such as will not admit of their being moulded to the different shapes which the ingenuity of the architect might devise. However, in order to render the present Work complete, and to obviate, as far as possible, every difficulty, several plates are introduced, illustrative of the various forms of arches, niches, &c.

Few things are more important than a clear idea of the mutual connection of the various parts of a building. The author has, therefore, introduced a section, in which he has endeavoured to show, from first principles only, the dependance which each part has upon some other.

The various trades connected with building, as PLASTERING, PAINTING, GLAZING, PLUMBING, &c. will be found to be treated of in as complete a manner as was practicable; these branches not admitting of any very scientific development.

A comprehensive Treatise on the FIVE ORDERS is subjoined to the trades accessary to building: these Orders, with their appropriate embellishments, form the basis and superstructure of architectural decoration. The parts of the Orders are drawn on a scale which speaks to the eye, and renders all farther detail unnecessary. The parts are given in modules and minutes; this being the best mode of exhibiting their proportions, so as to be most readily and clearly comprehended by the workman and student.

In order to increase the utility of the Work, to the BUILDER and CONTRACTOR, a select series of designs, in the modern style, accommodated to the various ranks of society, have been introduced; and, for the use of the ARCHITECTURAL STUDENT, that no accomplishment which might facilitate the operations of the draughtsman, or furnish the designer with more correct ideas, or more extensive views, may be wanting, the RULES of PROJECTION, and the PRINCIPLES of PERSPECTIVE, are presented; and in the most familiar and simple manner in which the subject could be conceived.

The Work concludes with a copious GLOSSARY of the most useful terms employed by architects and builders.

On the whole, the following Treatise will be found to contain a much greater variety of subjects than any similar work; and, in the method of treating the various articles, the studious reader will discover many things entirely new. Thus, for example, in the designs for roofs, several modes are brought forward, for the first time, interesting, both with respect to the disposition and joining of the timbers; and the examples which are given

will be found of the greatest utility to the practical builder, in regulating his ideas with respect to any design under consideration, however much it may differ from any of the forms exhibited here.

The schemes or diagrams are proportioned in their size to their probable utility; and the strictest regard has been paid to giving to all the parts of each figure their respective and just proportions.

Finally, from the important information collected, the natural arrangement adopted, and the numerous and valuable illustrations exhibited in the course of this Work, the Author flatters himself that he will be found to have rendered an important service to a numerous and highly meritorious class of his fellow-subjects; whilst even the most inattentive observer cannot but acknowledge that the Publisher has spared no expense to render the Work deserving of extensive patronage and general approbation. The grand principle of the undertaking is obvious: it is equally calculated to instruct the untaught, and to assist the intelligent; to promote a generous emulation, and at once to incite and satisfy enquiry into the elements and practice of those branches of science, than which no others are more conducive to the comfort and happiness of mankind.

P. NICHOLSON.

*London*, 1822.

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CONTENTS.



DIRECTIONS

THE NEW

# PRACTICAL BUILDER, &c.

## CHAPTER I.

### THE ELEMENTS OF GEOMETRY.

GEOMETRY is a science which considers the properties of lines and angles, as formed according to some certain law; as, also, the construction of all manner of figures, according to given *data*.

It is divided into two branches; one of which considers the relations, positions, and properties, of lines, so as to render a proposition clear to the understanding without the aid of compasses or other instruments; being demonstrated, by a continued chain of reasoning, from certain principles previously established and laid down as axioms; so that the conclusions from one truth become part of the *data* for the proof of a succeeding proposition. This, which is called the Theory of Geometry, is fully explained by EUCLID, in his celebrated "ELEMENTS," which have served as the basis of all succeeding treatises on the subject: and so much of those Elements as may be required in the practice of Architecture will be found included in the present work.

The other branch of geometry is entirely *practical*, and may be acquired without the theory, according to the directions hereafter given; although with a knowledge of the reasons of the rules it will be more satisfactory. It is this practical branch that enables the architect to regulate his designs, and the artizan to construct his lines, so as to enable him to execute the work. Without the aid of this branch of knowledge, the workman will be unfit for

any undertaking whatever; and, so long as he is ignorant of the methods of geometrical construction, he must remain under the control and direction of a superior in his own class.

The definitions and problems, which follow, are calculated to instruct the uninformed mechanic, and will qualify him for proceeding to the remaining parts of this treatise, wherein it will be found that the application of this branch of science is absolutely necessary.

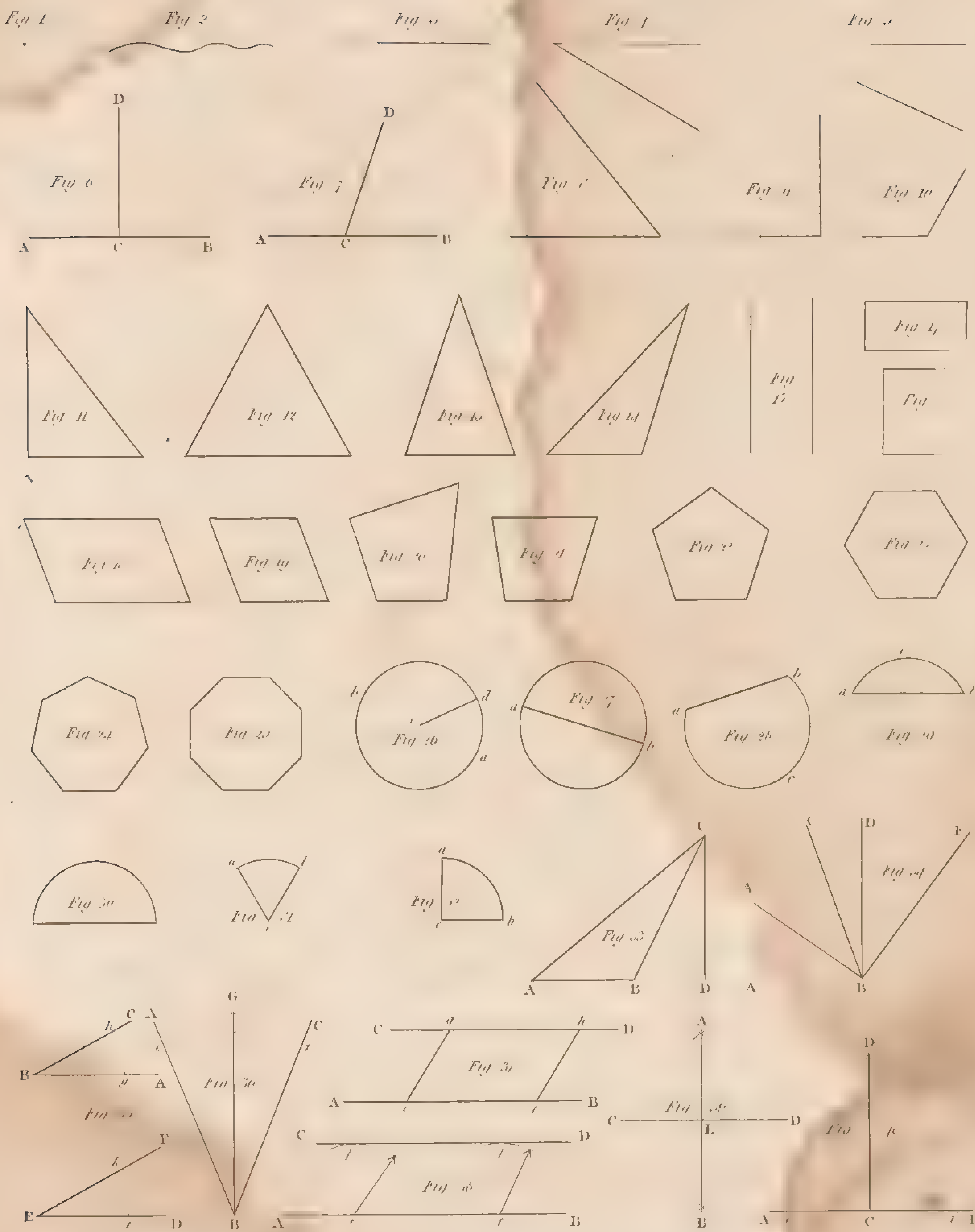
The uses of Geometry are not confined to Carpentry and Architecture: Astronomy, Navigation, Perspective, and numerous other branches, are entirely dependent upon it. "It conducts the soldier in the field, and the seaman on the ocean; it gives strength to the fortress, and elegance to the palace." In short, there is no mechanical profession that does not derive considerable advantage from it. One workman is superior to another, in proportion to his knowledge of the subject we are now commenting upon, and which we are about to explain.

The Terms are here as clearly defined as the nature of the subject will admit, and the Problems are put in a regular succession; so that nothing is introduced, in any problem, as taken for granted, but what has been explained in some problem previously given. This selection, though not very numerous, is sufficient to enable the student to proceed with the remaining parts of the work, to which it is specially adapted: and every attention has been paid to divest the diagrams of superfluous lines, without rendering them less intelligible.

## GEOMETRIC DEFINITIONS.

1. A Point is considered as that which has position without magnitude. *Practically*, a Point is the smallest visible mark upon a surface, as at *figure* 1, *plate* I.

2. A Line is considered as length, without breadth or thickness; having extension only in one direction, as *figures* 2 and 3, (*plate* I,) which may be conceived to be made by the trace of a point, pen, or pencil.



3. A Right or Straight Line is that which lies evenly between its extremes or ends. If two straight lines coincide in two points, all the intermediate points will coincide also.

Thus, *fig*. 3, (*pl.* I,) represents a straight line, and *fig*. 2, a curve, or crooked line: the latter may be formed either by regular inflexions, or portions of straight lines, or both.

4. A Superficies, or Surface, is that which is considered as having length and breadth without depth.

Thus the outward parts of any body, which are exhibited to the eye, are termed the *superficies* of that body.

5. A Plane Superficies or Plane Surface, is that on which a straight line, drawn through any given point, in any position, will coincide.

6. A Plane Figure, or Diagram, or Scheme, is the representation of any thing on a plane surface, by means of lines. When the lines are straight, the figure is said to be *rectilineal.*

7. An Angle is a space between two lines meeting in a point. A Plane Rectilineal Angle is the space between two straight lines so meeting.

Thus, *fig*. 4, (*pl.* I,) is a *plane rectilineal angle.*

8. Two straight lines are said to *converge,* when they meet each other, if *produced* or continued; as in *fig*. 5.

9. When one straight line stands upon another, and makes the angles on each side equal to each other, each of the equal angles is called a right angle, and the line which stands upon the other is called a *perpendicular* to that other line.

Thus, in *fig*. 6, (*pl.* I,) if the line CD stand upon AB, and make the angles on both sides of CD equal; each of these angles is a *right angle.* In *fig*. 7, the line CD does not make the angles on each side of it equal to each other: in this case, CD is said to stand at *oblique angles* to AB; and in the former case, *fig*. 6, CD is said to stand at right angles to AB.

10. An Acute Angle is that which is *less* than a right angle.

11. An Obtuse Angle is that which is *greater* than a right angle.

In *fig.* 7, as CD makes the angles on each side of it unequal, one of them must be greater than the other: the greater must, therefore, be an *obtuse angle,* and the less an *acute angle.* And, as the space around the point C is the same, whatever be the position of the line CD, with respect to AB, what the one angle has in excess above the right angle, the other will have as much in defect.

*Figure* 8, (*pl.* I,) is an *acute angle; fig.* 9, a *right angle;* and *fig.* 10, an *obtuse angle.*

12. A Plane Triangle is a space inclosed by three straight lines.

Thus, *figures* 11, 12, 13, and 14, are *triangles.*

13. A Right-angled Triangle is that which has one right angle.

Thus, *fig.* 11 is a *right-angled triangle.*

14. An Acute-angled Triangle is that which has all its angles *acute;* as *figures* 12 and 13.

15. An Obtuse-angled Triangle is that which has one *obtuse* angle; as *fig.* 14.

16. An Equilateral Triangle is that which has all its sides *equal;* as *fig.* 12.

17. An Isosceles Triangle is that which has two equal sides; as *fig.* 13.

18. A Scalene Triangle is that which has no two of its sides equal; as *fig.* 14.

19. Parallel Lines are lines on the same plane, which cannot meet, though produced or continued ever so far from each extremity (*fig.* 15.)

20. A Parallelogram is a figure whose opposite sides are *parallel.*

Thus, *figures* 16, 17, 18, and 19, are *parallelograms.*

21. When the parallelogram has one of its angles a right-angle, it is called a rectangle. Thus, *figures* 16 and 17 are *rectangles.*

22. When the sides of the rectangle are equal, it is called a square.

Thus, *fig.* 16 is a *square.*

23. When the two adjacent sides are unequal, the rectangle is called an oblong; as *fig.* 17.

24. When only two opposite angles of a parallelogram are equal, it is called a RHOMBUS; as *figures* 18 and 19.

25. When two adjacent sides of a rhombus are equal, it is called a RHOMBOID (pron. *rhom-bo-id)*; as *fig.* 19.

26. Every figure, inclosed by four straight lines, is called a QUADRANGLE or QUADRILATERAL. Thus, *figures* 16, 17, 18, 19, 20, and 21, are *quadrilaterals.*

27. When all the sides of a quadrilateral are unequal, it is called a TRAPEZIUM.

28. When two sides of the trapezium are parallel, it is called a TRAPEZOID; as *fig.* 21.

29. Equilateral and equiangular figures, contained by more than four straight lines, are called REGULAR POLYGONS.

30. A regular polygon of *five* sides, is called a PENTAGON; as *fig.* 22.

31. A regular polygon of *six* sides, is called a HEXAGON; as *fig.* 23.

32. A regular polygon of *seven* sides, is called a HEPTAGON; as *fig.* 24.

33. A regular polygon of *eight* sides, is called an OCTAGON; as *fig.* 25, and so on.

The words *enea, deca, undeca, dodeca,* having the termination *gon* subjoined, signify regular polygons of nine, ten, eleven, and twelve, sides. Other polygons are commonly expressed as such, with the number of sides.

34. A CIRCLE is a plain figure, contained under one line only, which is called its *circumference.* From the circumference, straight lines, called *radii,* being drawn to a certain point within the figure, are equal.

35. The point to which the equal lines from the circumference are drawn, is called the CENTRE of the circle. Thus, in *fig.* 26, *c* is the *centre,* and *c d* the *radius* of the circle *a b d.*

36. The DIAMETER of a circle is a straight line, drawn through the centre, and terminated by the circumference; as the line *a b*, *fig.* 27.

37. A CHORD of a circle is a straight line, drawn through the circle, and terminated by the circumference. Thus the line *a b*, *fig.* 28, is a *chord;* and *a b*, *fig.* 27, is a *chord passing through the centre.*

38. A SEMI-CIRCLE is the half of a circle, terminated by a diameter and the semi-circumference. Thus, in *fig.* 27, the diameter *a b* divides the circle into two semi-circles.

39. A SEGMENT of a circle is a portion cut off by a chord, and the part of the circumference intercepted by the chord. Thus, *a b c, figures* 28 and 29, are *segments*; and *fig.* 30, though a semi-circle, is still a segment, terminated by the diameter, instead of a lesser chord.

40. A SECTOR of a circle is the portion contained by two radii and the intercepted part of the circumference. Thus, *a b c, fig.* 31, is the *sector* of a circle.

41. The QUADRANT of a circle is a sector contained by two radii, at a right-angle with each other, and the intercepted part of the circumference; as, *a b c,* in *fig.* 32.

42. An ARC of a circle is any portion of its circumference.

43. The ALTITUDE of a figure is a straight line drawn from the vertical angle, perpendicular to the opposite side, or to the opposite side produced or continued. Thus, CD, *fig.* 33, is the altitude of the triangle ABC, drawn from the vertical angle C to the opposite side AB produced to D.

## 44. NOTATION.

When several angles unite at a point, each angle is indicated by *three letters*, the middle letter denoting the *angular point*, and the others the sides containing that angle. Thus, in *fig.* 34, ABC, ABD, ABE, the middle letter B indicates the angular point: in the first, AB, BC, the two sides; in the second, AB, BD, the sides; and, in the third, AB, BE, the sides.

## 45. EXPLANATION OF TERMS.

An AXIOM is a self-evident truth.

A THEOREM is a truth which becomes evident by a process of reasoning, called a *demonstration*.

A Problem is a thing required to be done, or a question proposed for solution.

A Lemma is a truth premised to facilitate either the demonstration of a theorem, or the solution of a Problem.

A Proposition is the common name of a Theorem or Problem.

A Corollary is a consequence or deduction which follows from a Proposition.

A Scholium is an explanatory remark upon one or more preceding Proposition or Propositions.

An Hypothesis is a *supposition* made either in the enunciation of a Proposition, or in the course of a demonstration.

## 46. AXIOMS.

1. Things which are equal to the same thing, or things, are equal to one another.
2. If equals be added to equals, the wholes will be equal.
3. If equals be taken from equals, the remainders will be equal.
4. If equals be added to unequals, the wholes will be unequal.
5. If equals be taken from unequals, the remainders will be unequal.
6. Things which are double of the same thing, are equal to one another.
7. Things which are halves of the same thing, are equal to one another.
8. Magnitudes which coincide with one another, that is, which exactly fill the same space, are equal to one another.
9. The whole is greater than its part.
10. Only one straight line can be drawn from one point to another.
11. Two straight lines cannot be drawn through the same point, parallel to the same straight line, without coinciding with one another.

## 47. POSTULATES, or DEMANDS.

1. Let it be granted that a straight line may be drawn from any one point to any other.

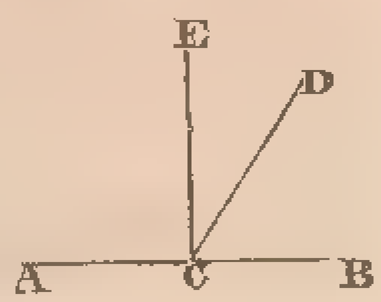
2. That a terminated straight line may be *produced,* or continued, to any length.

3. That a circle may be described from any centre, and at any distance from that centre, or with any radius.

## THEOREMS.

### THEOREM 1.

48. Any straight line, CD, which meets another straight line, AB, makes with it two adjacent angles, ACD, BCD; which, taken together, are equal to two right angles.*

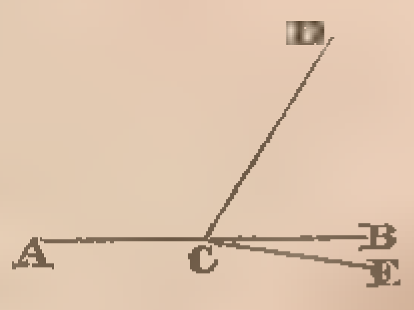



At the point C, let the straight line CE be drawn, perpendicular to AB. The angle ACD is the sum of the angles ACE and ECD; therefore ACD+DCB shall be the sum of the three angles ACE, ECD, DCB, (*Axiom* 2, page 15). Now the angle ACE is a *right angle,* and the sum of the angles ECD, DCB, make a right angle; therefore the sum of the two angles ACD, BCD, is equal to two right angles.

49. Corollary.—If one of the angles ACD, BCD, is a right angle, the other is, also, a right angle.

### THEOREM 2.

50. If the sum of two adjacent angles, ACD, DCB, be equal to two right angles, the exterior sides form one continued straight line.



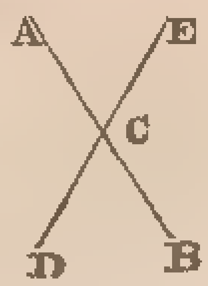

For, if CB is not the continuation of AC, let CE be its continuation; then the sum of the angles ACD, DCE, is equal to two right angles, (*theorem* 1,) but, by hypothesis, the sum of the angles ACD, DCB, is equal to two right angles; therefore the two angles ACD, DCE, is equal to the two angles

* The signs used in Algebraic Notation are explained hereafter; but, as several may previously occur, it may here be noticed that + *(plus)* signifies *more,* or one quantity or thing added to another: The sign − *(minus)* signifies *less,* or one quantity subtracted from another: = means is, or are, equal to: × into, or multiplied by: ÷ divided by, as $30 \div 3$ or $\frac{30}{3} = 10$.

ACD, DCB (*Ax.* 1, page 15); and, taking from each of these equals the angle ACD, there will remain the angle DCE, equal to DCB, a part equal to the whole, which is impossible (*Ax.* 9, page 15).

THEOREM 3.

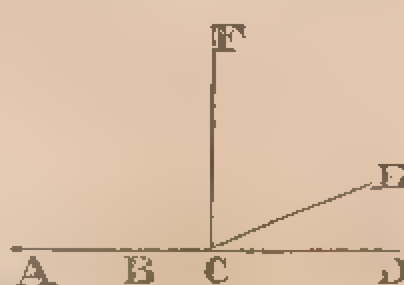
51. If two straight lines, AB, DE, cut one another, the opposite angles shall be equal to one another.




For, since DE is a straight line, the sum of the two angles ACD, ACE, is equal to two right angles (*theorem* 1); and, because AB is a straight line, the sum of the angles ACE, ECB, is equal to two right angles (*theorem* 1); therefore the sum of the angles ACD, ACE, is equal to the sum of the angles ACE, ECB; and, taking away from each the common angle ACE, there will remain the angle ACD, equal to the vertical opposite angle ECB.

THEOREM 4.

52. Two straight lines, which have two common points, coincide entirely throughout their whole extent.

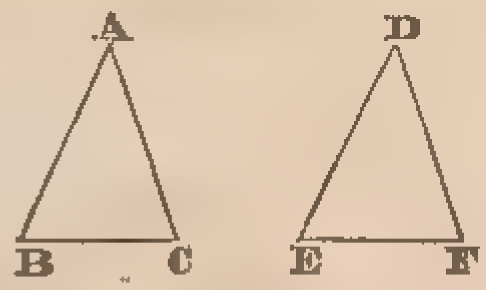



Let A and B be the two common points; in the first place, the two lines can make but one from A to B, (*Ax.* 10, *p.* 15). If it were possible that they could separate, let C be the point of separation, and let us suppose that one of them takes the direction CD, and the other CE.

At the point C suppose CF to be drawn, perpendicular to AC; then, because ACD is, by hypothesis, a straight line, the angle FCD is a right angle; (*Def. art.* 9;) in like manner, because ACE is supposed to be a straight line, the angle FCE is a right angle; therefore the angles FCD, FCE, are equal; but this is impossible (*Ax.* 9, *page* 15); therefore the two straight lines, which have two common points, A and B, cannot separate, but must form one continued line.

### THEOREM 5.

53. Two triangles are equal when, in the one, an angle and the two sides which contain it are equal, in the other, to an angle and the two sides which contain it.

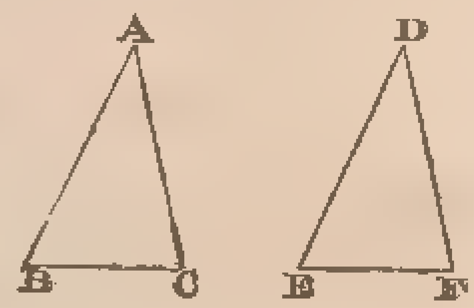



Let the angle A be equal to the angle D, the side AB equal to DE, and the side AC equal to DF; then the triangles ABC, DEF, shall be equal.

Suppose the triangle ABC to be placed upon the triangle DEF, so that AB may be upon DE; then, because the angles A and D are equal, AC will fall upon DF; and, because AB is equal to DE, and AC equal to DF, the point B will coincide with E, and C with F: therefore, the base BC will coincide with the base EF (*theorem* 4); and, since the sides of the triangles coincide, the other two angles must also coincide; that is, they must be equal to each other.

### THEOREM 6.

54. Two triangles are equal when a side and two adjacent angles of the one are respectively equal to a side and two adjacent angles of the other.




Let the side BC be equal to the side EF, the angle B equal to the angle E, and the angle C equal to the angle F, the triangles shall be equal.

For, suppose the triangle ABC to be placed upon the triangle DEF, so that their bases, BC and EF, may coincide; then, because the angles B and E are equal, the straight line BA will fall upon ED; and, because the angles C and F are equal, the straight line CA will fall upon FD: therefore, the three sides of one triangle will coincide with the three sides of the other; and, consequently, the triangles themselves will be equal: and, since therefore the sides of the triangles coincide, the corresponding angles will be equal.

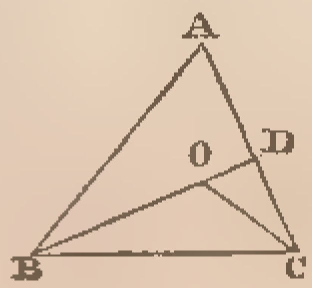
### THEOREM 7.

55. Any two sides of a triangle are together equal to more than a third side.


For, in the triangle, ABC, the straight line BC is the shortest line that can be drawn from B to C; therefore the sum of the two sides, BA, AC, is greater than BC.

### THEOREM 8.

56. If from any point, as O, within a triangle, ABC, there be drawn two straight lines, OB, OC, one to each extremity of any side, as BC, their sum is less than the sum of the other two sides of the triangle.



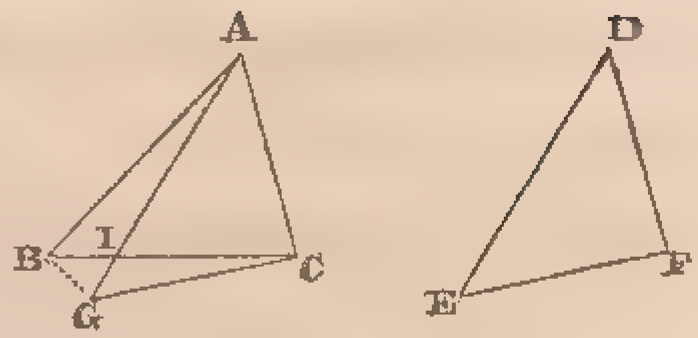

Produce BO till it meet AC in D; the line OC is less than the sum of the two lines OD, DC (*theorem* 7); and, adding to these unequals the line BO, the sum of the two lines, BO, OC, is less than the sum of the three lines BO, OD, DC (*ax.* 4, *p.* 15); that is, the sum of the two lines BO, OC, is less than the sum of the two lines BD, DC.

In like manner, BD is less than the sum of the two lines BA, AD; and, adding DC to these unequals, the sum of the two straight lines, BD, DC, is less than the sum of the three straight lines BA, AD, DC; that is, the two straight lines BD, DC, are less than the two straight lines BA, AC; but the two straight lines BO, OC, have been shown to be less than the two straight lines BD, DC; and, therefore, much less is the sum of the two straight lines BO, OC, than that of the two sides BA, AC, of the triangle ABC.

### THEOREM 9.

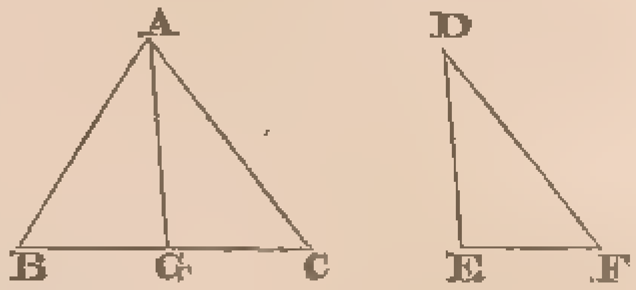
57. If any two sides AB, AC, of a triangle, ABC, are equal to two sides DE, DF, of another triangle DEF, each to each, and if the angle BAC, contained by the sides, AB, AC, be greater than the angle EDF, contained by the sides ED, DF, the base BC of the triangle which has the greater angle shall be greater than the base EF of the other triangle.

Make the angle CAG equal to D, take AG equal to DE or AB, and join CG; and because the two triangles CAG, DEF, have an angle of the one equal to an angle of the other, and the sides which contain these angles are equal, CG shall be equal to EF (*theorem* 5). Now there may be three cases, according as the point G falls without the triangle ABC, or on the side BC, or within the triangle.

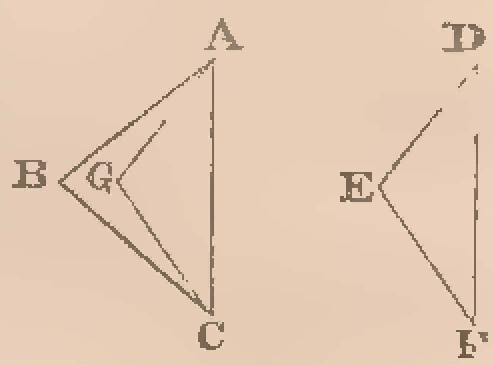



Case 1.—Because GC is less than the sum of the two straight lines GI, IC; and AB less than the sum of the two straight lines AI, IB: therefore, the sum of the two straight lines GC, AB, is less than the sum of the four straight lines GI, IC, AI, IB; that is, the sum of the two straight lines GC, AB, is less than the sum of the two straight lines AG, BC; but AG is equal to AB, therefore GC is less than BC; but GC = EF, therefore EF is less than BC.

Case 2.—If the point G fall on BC, it is evident that GC, or its equal EF, is less than BC.



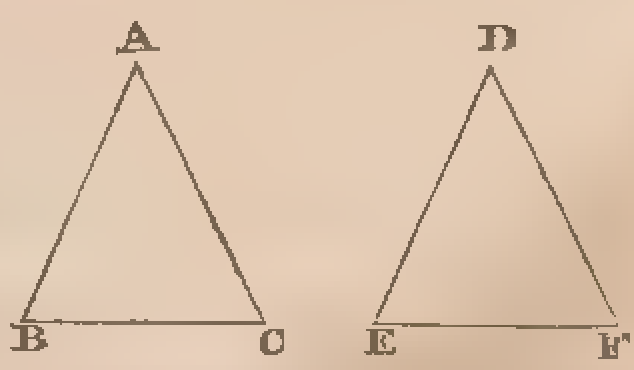

Case 3.—Lastly, if the point G fall within the triangle ABC, by *theorem* 8, we have the sum of the two straight lines AG, GC, less than the sum of the two straight lines AB, BC; but since AB is equal to AG, we shall have GC less than BC; and, consequently, EF less than BC.




THEOREM 10.

58. One triangle is equal to another, when the three sides of the first are respectively equal to the three sides of the second.

Let the side AB be equal to DE, AC equal to DF, and BC equal to EF; then shall the angle A be equal to the angle D, the angle B equal to the angle E, and the angle C equal to the angle F. For, if the angle A were greater than D, then, as the two sides AB, AC, are equal to the two sides DE, DF, each to each, it would follow (*theorem* 9) that the side BC



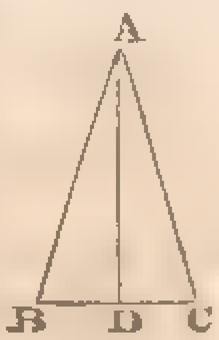
would be greater than EF; and, if the angle A were *less* than the angle D, BC would be less than EF; therefore, the angle A can neither be greater nor less than the angle D; the angle A must therefore be equal to the angle D. In like manner, it may be proved that the angle B is equal to E, and C equal to F.

59. Corollary.—Whence it appears that, in two equal triangles, the equal angles are opposite to the equal sides; for the equal angles A and D are opposite to the equal sides BC and EF.

THEOREM 11.

60. The angles opposite to the equal sides of an isosceles triangle are equal.

Let the side AB be equal to AC; then shall the angle C equal the angle B. For, suppose AD to be drawn from the vertex A to the middle point D, of the base BC; then the two triangles ADB, ADC, will have the two sides AB, BD, of the one equal to the two sides AC, CD, of the other, each to each; and AD is common to both: therefore the angle B shall be equal to the angle C.



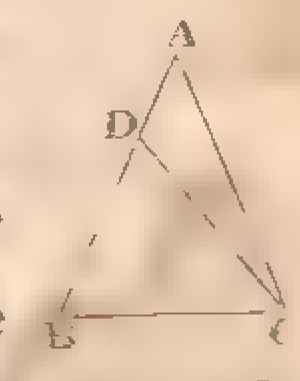

61. Corollary 1.—Hence every equilateral triangle is also equiangular.

62. Corollary 2.—A straight line drawn from the vertex of an isosceles triangle to the middle of the base will bisect the vertical angle, and be perpendicular to the base.

THEOREM 12.

63. If two angles of a triangle be equal, the opposite sides shall be equal, and the triangle shall be isosceles.

Let the angle ABC be equal to ACB, the side AC shall be equal to the side AB.

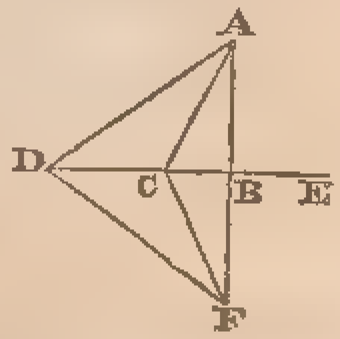



For, if the two sides AB, AC, are not equal, let AB be greater than AC, and from BA cut off BD, equal to CA, and join CD; the angle DBC is, by hypothesis, equal to the angle ACB, and the two sides DB, BC, are equal to the two sides AC, CB; therefore the triangle DBC is equal

to the triangle ACB, the less to the greater, which is impossible (*ax.* 9, *p.* 15); therefore AB cannot be unequal to AC, but must be equal to it.

THEOREM 13.

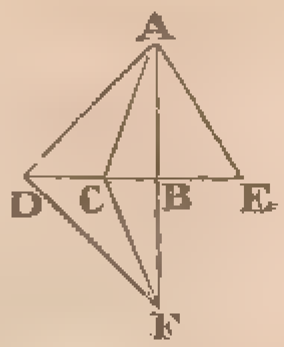
64. From a point A, without a straight line DE, only one perpendicular can be drawn to that line.




For, suppose it were possible to draw AB, AC, perpendicular from the same point A, upon the straight line DE; produce one of them, AB, to F, so that BF may be equal to AB, and join FC; and, because AB is equal to BF, and BC is common to the two triangles ABC, FBC, and the angles ABC and FBC are equal; the angle ACB is equal to FCB (*theorem* 5); therefore AC and CF must be a continued line (*theorem* 2); and so, through the two points A, F, two straight lines, AF and ACF, may be drawn, that do not coincide; which is impossible: and, therefore, it is equally impossible that two perpendiculars can be drawn from the same point to the same straight line.

THEOREM 14.

65. Of all the lines that can be drawn from a given point A, to a given straight line DE, the perpendicular is the shortest; and of the other lines, that which is nearer the perpendicular is less than that which is more remote; and those two lines, on opposite sides, and at equal distances, from the perpendicular, are equal.




Produce the perpendicular, so that BF may be equal to AB, and draw the straight lines AC, AD, and AE, to meet DE in C, D, and E, and join FC, FD, &c.

The triangles BCF and BCA are equal (*theorem* 5); for BF is equal to BA, and BC common; therefore CF is equal to CA. Now AF is less than AC + CF (*theorem* 7); therefore, taking the halves, AB is less than AC; that is, the perpendicular is the shortest line that can be drawn from A to DE.

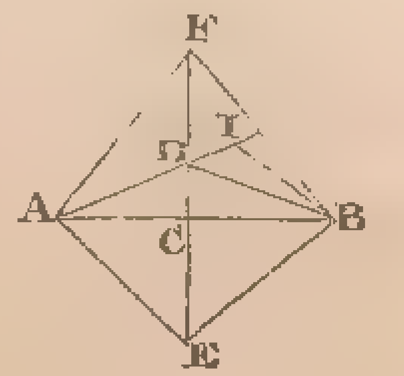
Next, suppose BE equal to BC; then the triangles ABE and ABC will be equal (*theorem* 5), for they have BA common, and the angles ABE and ABC

equal; therefore AE is equal to AC; that is, two oblique lines, equally distant from the perpendicular, on opposite sides, are equal.

In the triangle ADF, the sum of AC and CF is less than the sum of AD and DF (*theorem* 8); therefore AC, the half of AC + CF, is less than AD, the half of AD + DF; that is, the oblique line, which is farther from the perpendicular, is greater than that which is nearer to it.

### THEOREM 15.

66. If through the point C, the middle of the straight line AB, a perpendicular be drawn to that line, every point in the perpendicular is equally distant from the extremities of the line AB, and every point out of the perpendicular is unequally distant from these extremities.

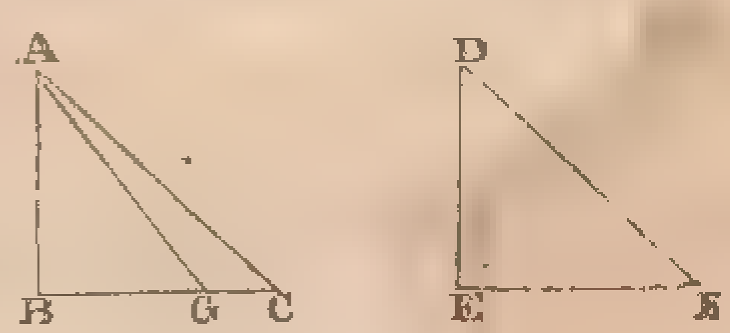



Because AC is equal to BC, the two oblique lines AD, BD, which are equally distant from the perpendicular, are equal (*theorem* 14). The same is also true of the two oblique lines AE, EB, and of the two oblique lines AF, FB, &c. Therefore, every point in the perpendicular is equally distant from the ends of the line.

Let I be a point out of the perpendicular. If IA, IB, be joined, one of them will cut the perpendicular in D; therefore, drawing DB, we have DB equal to DA: but IB is less than ID + DB, and ID + DB is equal to ID + DA equal to IA; therefore IB is less than IA: that is, any point out of the perpendicular is unequally distant from the extremities A and B.

### THEOREM 16.

67. Two right-angled triangles are equal if the hypothenuse and a side of the one be equal to the hypothenuse and a side of the other.




Let the hypothenuse (or longest side) AC be equal to the hypothenuse DF, and the side AB equal to the side DE, and the right-angled triangle ABC shall be equal to the right-angled triangle DEF.

The proposition will be evidently true if it can be proved that BC is equal to EF (*theorem* 10). Let us suppose, if it be possible, that these sides are unequal, and that BC is the greater. Take BG equal to EF, and join AG. The triangles ABG and DEF, having AB equal to DE, and BG equal to EF, by hypothesis, and also having the angle ABG equal to DEF, they will be equal (*theorem* 5) : therefore AG is equal to DF; but DF is equal to AC; therefore AG is equal to AC: that is, two oblique lines, one more remote from the perpendicular than the other, are equal; which is impossible (*theorem* 15): therefore, BC is not unequal to EF, and hence the triangle ABC is equal to the triangle DEF.

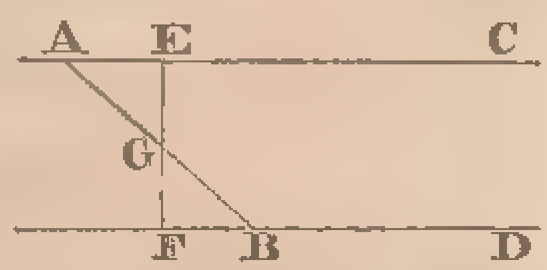
### THEOREM 17.

68. Two straight lines perpendicular to a third are parallel.


For, if the straight lines AC, BD, be not parallel, they will meet on one side or the other of the line AB; let them meet in O; then AC and OB are both perpendicular to AB, from the same point O; which is impossible (*theorem* 13).

### THEOREM 18.

69. If two straight lines, AC and BD, make with a third, AB, the sum of the two interior angles CAB, ABD, equal to two right angles, these two straight lines are parallel.

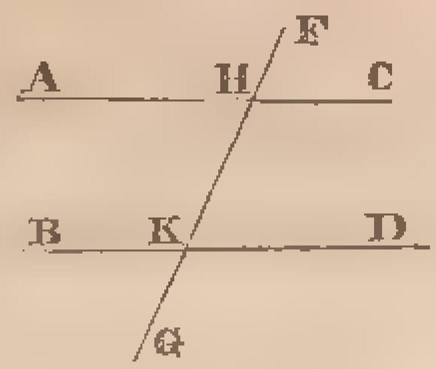



From G, the middle of AB, draw EGF, perpendicular to AC: then, since the sum of the angles ABD, ABF, is equal to two right angles (*theorem* 1), and, by hypothesis, the sum of the two angles ABD, BAC, is also equal to two right angles; therefore, the two angles ABD, ABF, are together equal to the sum of the two angles ABD, BAC; and, taking away the common angle ABD, there remains the angle ABF = BAC; that is, GBF equal to GAE. But the angles BGF and AGE are also equal (*theorem* 3); and, since BG is equal to GA, therefore the triangles BGF and AGE, having a side and two adjacent angles of the one equal to a side and two adjacent angles of the other, are equal (*theorem* 6),

and the angle BFG is equal to AEG; but AEG is, by construction, a right angle; therefore, BFG is also a right angle; and, since GEC is a right angle, the straight lines EC and FD are perpendicular to EF, and are, therefore, parallel to each other (*theorem* 17).

### THEOREM 19.

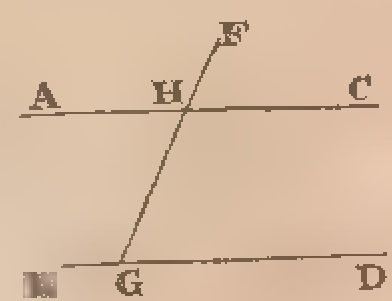
70. If two straight lines, AC, BD, make with a third, HK, the alternate angles, AHK and HKD, equal, the two lines are parallel.




For, adding KHC to each of the angles AHK, HKD, the sum of the angles AHK, KHC, is equal to the sum of the angles HKD, KHC; but the angles AHK, KHC, are together equal to two right angles; therefore, also, the angles HKD, KHC, is also equal to two right angles; and, consequently, AC is parallel to BD (*theorem* 18).

### THEOREM 20.

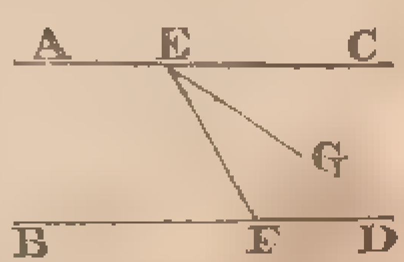
71. If two straight lines, AC, BD, are cut by a third, FG, so as to make the exterior angle, FHC, equal to the interior and opposite angle, HGD, on the same side, the two lines are parallel.




For, since the angle FHC is equal to the angle AHG, and since, when AC is parallel to BD, the angle AHG is equal to HGD (*theorem* 19), therefore the angle FHC is equal to HGD.

### THEOREM 21.

72. If a straight line, EF, meet two parallel straight lines, AC, BD, the sum of the inward angles CEF, EFD, on the same side, will be equal to two right angles.



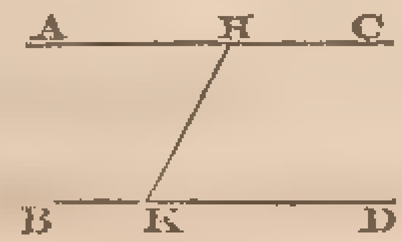

For, if not, suppose EG to be drawn through E, so that the sum of the angles GEF and EFD may be two right angles; then EG will be parallel to BD (*theorem* 18); and thus, through the same point E, two straight lines, EG, EC, are drawn, each parallel to BD; which is impossible (*ax.* 11, *p.* 15); therefore no straight

line that does not coincide with AC, is parallel to BD; wherefore the straight line AC is parallel to BD.

73. Corollary.—If a straight line is perpendicular to one of two parallel straight lines, it is also perpendicular to the other.

### THEOREM 22.

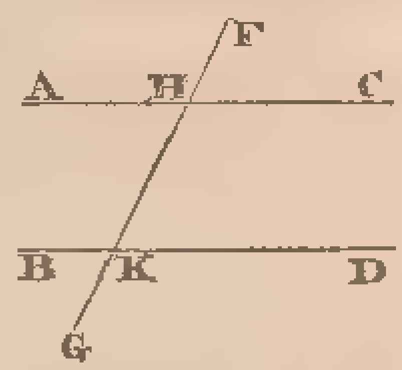
74. If a straight line, HK, meet two parallel straight lines, AC, BD, the alternate angles, AHK, HKD, shall be equal.




For, the sum of the angles CHK, HKD, is equal to two right angles; and the sum of the angles BKH, AHK, is also equal to two right angles; therefore the angle HKD must be equal to AHK.

### THEOREM 23.

75. If a straight line, FG, cut two parallel straight lines, AC, BD, the exterior angle, FHC, is equal to the interior and opposite angle, HKD.

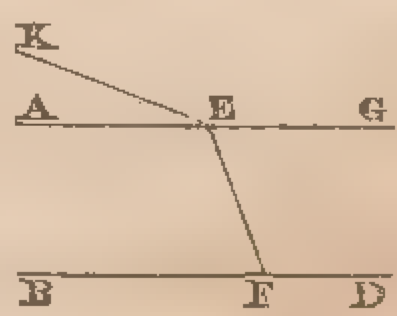



For, since the angle FHC is equal to the angle AHK (*theorem* 3), and the angle AHK equal to the angle HKD; therefore the angle FHC is equal to the angle HKD.

### THEOREM 24.

76. If a straight line, EF, meet two other straight lines, EG, FD, and make the two interior angles, EFD, FEG, on the same side, less than two right angles, the lines EG, FD, meet, if produced, on the side of EF, on which the angles are less than two right angles.

For, if they do not meet on that side, they are either parallel, or else they meet on the other side. Now they cannot be parallel, for then the two interior angles would be equal to two right angles, instead of being less. Again, to show that they cannot meet on the other side, suppose EA to be parallel to DFB; then, because the sum of the angles EFD, FEG, is, by hypothesis, less than two right angles, that is, less than the sum of the two angles,

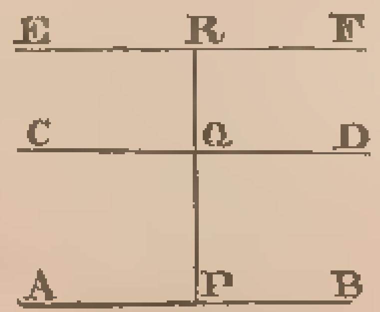


FEK, FEG (*theorem* 1), and EFD is equal to FEA (*theorem* 20); therefore the sum of the two angles FEA, FEG, is less than the sum of the two angles FEK, FEG; and, taking FEG from both, FEA is less than FEK: hence, FB and EK must be on opposite sides of EA; and, therefore, can never meet.

The truth of this proposition is assumed as an axiom in the Elements of Euclid, and made the foundation of parallel lines.

### THEOREM 25.

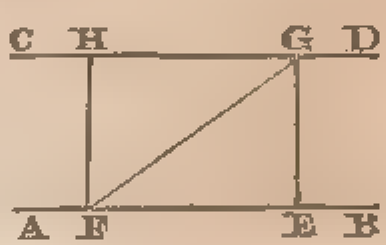
77. Two straight lines, AB, CD, parallel to a third, EF, are parallel to one another.




Draw the straight line PQR, perpendicular to EF. Because AB is parallel to EF, the line PR shall be perpendicular to AB; and, because CD is parallel to EF, the line PR is also perpendicular to CD: therefore AB and CD are perpendicular to the same straight line PQ; hence they are parallel (*theorem* 17).

### THEOREM 26.

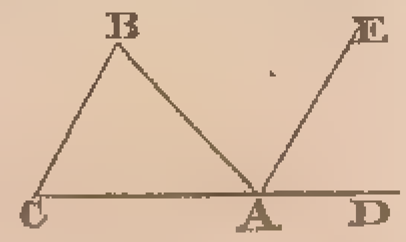
78. Two parallel straight lines are every where equally distant.




Let AB, CD, be two parallel straight lines. From any points, E and F, in one of them, suppose perpendiculars EG, FH, to be drawn; these, when produced, will meet the others at right angles, in H and G. Join FG; then, because FH and EG are both perpendicular to AB, they are parallel (*theorem* 17); therefore, the alternate angles, HFG, FGE, which they make with FG are equal (*theorem* 22): and, because AB is parallel to CD, the alternate angles, GFE, FGH, are also equal; therefore, the two triangles, GEF, FHG, have two angles of the one equal to two angles of the other, each to each; and the side FG, adjacent to the equal angles, common; the triangles are therefore equal (*theorem* 6); and FH is equal to EG; that is, any two points, F, E, on the one of the lines, are equidistant from the other line.

### THEOREM 27.

79. In any triangle, if one of the sides be *produced,* the exterior angle is equal to both the interior and opposite angles; and the three interior angles are equal to two right angles.




Let ABC be a triangle; produce any one of its sides, AC towards D; and from the point A, let AE be drawn, parallel to BC; and, because of the parallels CB and AE, and the angle EAD = C, and the angle EAB = B (*theorems* 22, 23); therefore the sum of the two angles, EAD, EAB, is equal to the sum of the two angles C and B; that is, since the angle BAD is equal to the sum of the two angles BAE, EAD, the angle BAD is equal to the sum of the angles B, C. Hence the outward angle is equal to the sum of the inward opposite angles.

Again, because the angle BAD is equal to the sum of the angles B and C, add to each the angle BAC, and the sum of the two angles BAC, BAD, will be equal to the sum of the three angles BAC, B, C, or the three angles of the triangle; but the sum of the two angles BAC, BAD, is equal to two right-angles (*theorem* 1); therefore the sum of the three angles of a triangle is equal to two right angles.

80. Corollary 1.—If two angles of one triangle be equal to two angles of another triangle, each to each, the third angle of the one shall be equal to the third angle of the other, and the triangles shall be equi-angular.

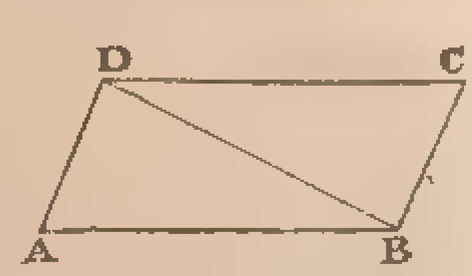
81. Corollary 2.—A triangle can have only one right angle.

82. Corollary 3.—In any right-angled triangle the sum of the two acute angles is equal to a right angle.

83. Corollary 4.—In an equilateral triangle each of the angles is one-third of two right angles.

THEOREM 28.

84. The opposite sides of a parallelogram are equal, as well as the opposite angles.




Draw the diagonal BD. The triangles ADB, DBC, have the common side DB; also, because of the parallels, AB, CD, the angle ABD is equal to CDB (*theorem* 22); and, because of the parallels AD, BC, the angle ADB is equal to DBC; therefore the triangles (*theorem* 6) and the sides AB, DC, which are opposite the equal angles, are equal. In like manner AD and BC are equal; therefore the opposite sides of the parallelogram are equal.

Again, from the equality of the triangles, it follows, that the angle A is equal to the angle C; and it has been shown that the angles ADB, BDC, are respectively equal to the angles CBD, DBA; therefore the whole angle ADC is equal to the whole angle ABC, and thus the opposite angles are equal.

85. Corollary.—Two parallels, AB, CD, comprehended between two other parallels, AD, BC, are equal.

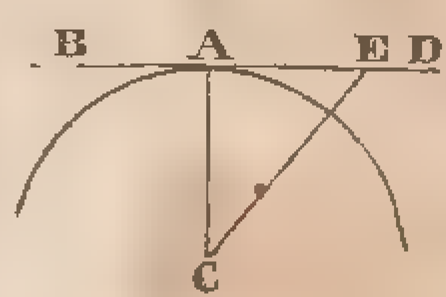
THEOREM 29.

86. If the opposite sides of a quadrilateral be equal, the figure is a parallelogram.

For, drawing the diagonal BD, (as above,) the triangles ABD, BDC, have the three sides equal, each to each; therefore the angle ADB, opposite to the side AB, is equal to the angle CBD, opposite to the side CD (*theorem* 10); hence the side AD is parallel to BC (*theorem* 19). For the like reason AB is parallel to CD: therefore the quadrilateral, ABCD, is a parallelogram.

THEOREM 30.

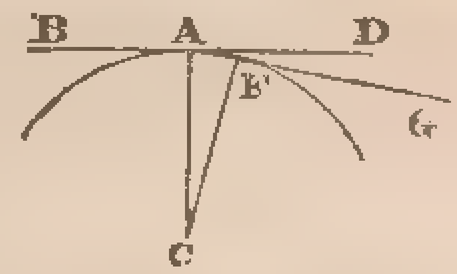
87. A straight line, BD, drawn perpendicular to the extremity of a radius, CA, is a *tangent* to the circumference.




For every oblique line, CE, is longer than the perpendicular CA (*theorem* 15); therefore the point E must be without the circle; and since this is true of every point in the line BD, except the point A, the line BD is a *tangent* (*def.* 9, *p.* 11).

THEOREM 31.

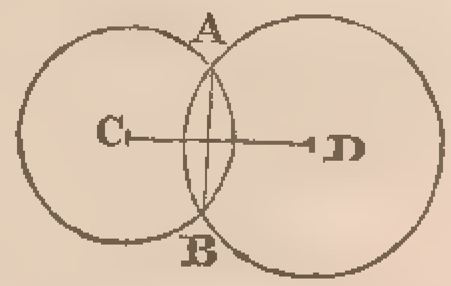
88. Only one tangent can be drawn from a point, A, in the circumference of a circle.




Let BD be a tangent at A, in the circumference, described with the radius CA; and let AG be another tangent, if possible; then, as CA would not be perpendicular to AG, another line, CF, would be perpendicular to AG, and so CF would be less than CA (*theorem* 14); therefore F would fall within the circle, and AF, if produced, would cut the circumference.

THEOREM 32.

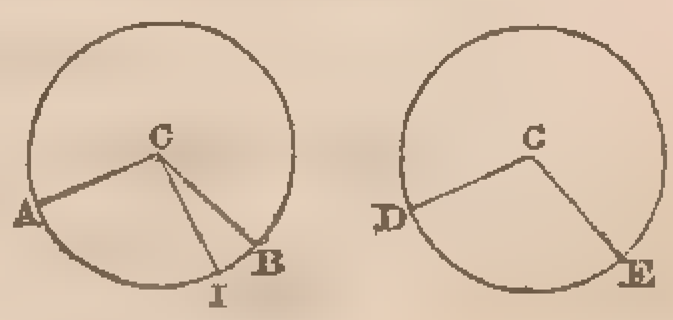
89. If two circumferences cut each other, the straight line which passes through their centres shall be perpendicular to the chord which joins the points of intersection, and shall divide it into two equal parts.




For the line AB, which joins the points of intersection, being a common chord to the two circles; if, through the middle of this chord, a perpendicular be drawn, it will pass through the points C, D, the centres of the two circles. But only one line can be drawn through two given points; therefore the straight line which passes through the centres is a perpendicular to the middle of the common chord.

THEOREM 33.

90. In the same circle, or in equal circles, equal angles ACB, DCE, at the centre, intercept equal arcs, AB, DE, on the circumference; and conversely, if the arcs AB, DE, be equal, the angles ACB and DCE are also equal.




If the angle ACB be equal to DCE, these two angles may be placed on each other; and, as their sides are equal, the point A will fall on D, and the point B on E; but then the arc AB must also fall on DE; for, if the two arcs did not coincide, there would be, in one or the other, points unequally distant from the centre; therefore the arc AB is equal to DE.

Next, if the arc AB be equal to DE, the angle ACB shall be equal to DCE; for, if they are not equal, let ACB be the greater, and take ACI equal to DCE; then, by what has been demonstrated, AI is equal to DE; but, by hypothesis, the arc AB is equal to DE; therefore the arc AI is equal to AB, which is impossible: therefore the angle ACB is equal to DCE.

### THEOREM 34.

91. An angle, ACB, at the centre of a circle, is double of the angle at the circumference, upon the same arc, AB.

*Fig.* 1.

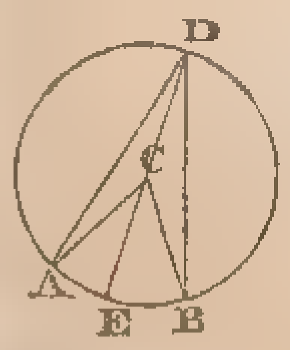
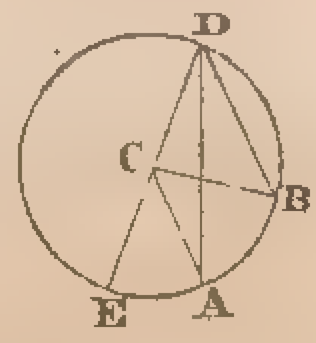



*Fig.* 2.




Draw DC, (*fig.* 1,) and produce it to E. First, let the angle at the centre be within the angle at the circumference, then the angle ACE is equal to the sum of the angles CAD, CDA (*theorem* 27); but, because CA is equal to CD, the angle CAD is equal to CDA (*theorem* 11); therefore the angle ACE is equal to twice the angle CDA. By the same reason the angle BCE is equal to twice the angle CDB; therefore the whole angle ACB is double the whole angle ADB.

Next, let the angle at the centre (*fig.* 2,) be without the angle at the circumference. It may be demonstrated, as in the first case, that the angle ECB is equal to twice the angle EDB, and that the angle ECA, a part of the first, is equal to twice EDA, a part of the second; therefore, the remainder, ACB, is double the remainder ADB.

### THEOREM 35.

92. The angles, ADB, AEB, in the same segment, AEB, of a circle, are equal to one another.

*Fig.* 2.

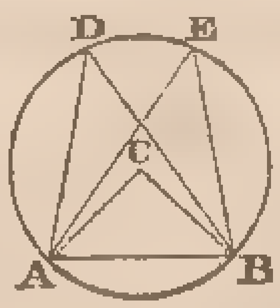
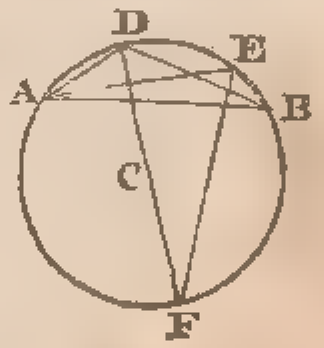



*Fig.* 2.

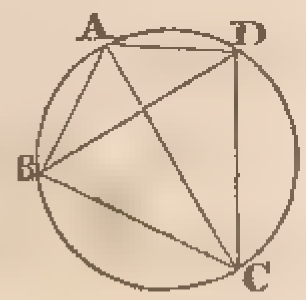



Let C (*fig.* 1) be the centre of the circle; and, first, let the segment AEB be greater than a semi-circle. Draw CA, CB, to the ends of the base of the segment; then each of the angles, ADB, AEB, will be half of the angle ACB (*theorem* 34); therefore the angles ADB and AEB are equal.

Next, let the segment AEB (*fig*. 2,) be less than a semi-circle; draw the diameter DCF, and join EF; and, because the segment ADEF is greater than a semi-circle, by the first case, the angle ADF is equal to AEF. In like manner, because the segment BEDF is greater than a semi-circle, the angle BDF is equal to the angle BEF; therefore the whole angle ADB is equal to the whole angle AEB.

THEOREM 36.

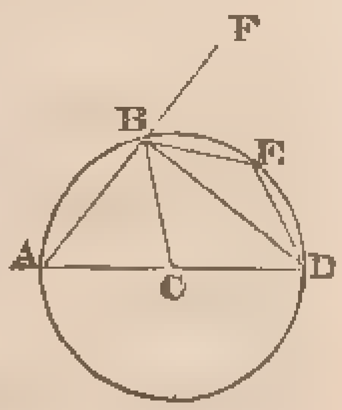
93. The sum of the opposite angles of any quadrilateral, ABCD, inscribed in a circle, is equal to two right angles.




Draw the diagonals AC, BD. In the segment ABCD, the angle ABD is equal to ACD; and, in the segment CBAD, the angle CBD is equal to CAD (*theorem* 35); therefore the whole angle ABC is equal to the sum of the two angles ACD, CAD; and, adding ADC, the sum of the two angles, ABC, ADC, is equal to the sum of the three angles. Now these three angles are the angles of the triangle ADC, and therefore equal to two right angles (*theorem* 27): therefore the sum of the two angles ABC, ADC, is equal to two right angles. In the same manner it may be demonstrated that the sum of the two angles BAD, BCD, is equal to two right-angles.

THEOREM 37.

94. An angle ABD, in a semi-circle, is a right angle; an angle BAD, in a segment greater than a semi-circle, is less than a right angle; and an angle, BED, in a segment less than a semi-circle, is greater than a right angle.



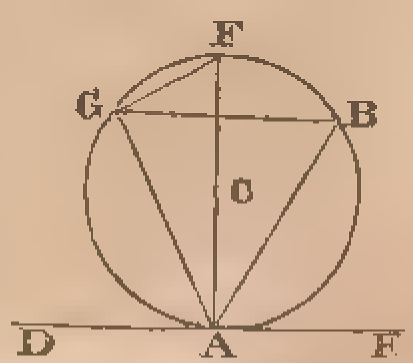

Produce AB to F, draw BC to the centre, and, because CA is equal to CB, the angle CBA is equal to CAB (*theorem* 11). In like manner, because CD is equal to CB, the angle CBD is equal to CDB; therefore the sum of the two angles CBA, CBD, is equal to the sum of the two angles CAB, CDB; that is, the angle ABD is equal to the sum of the two angles CAB CDB; but this last sum is equal to the angle DBF (*theorem* 27); therefore the angle ABD is equal to the angle DBF: but, when the angles are equal on each side of a

straight line which meets another, each of these angles is a right angle; therefore each of the angles ABD and DBF is a right angle; and, consequently, the angle ABD in a semi-circle is a right angle.

Again, because in the triangle ABD, the angle ABD is a right angle; therefore BAD, which is manifestly in a segment less than a semi-circle, is less than a right angle: and, lastly, because ABED is a quadrilateral in a circle, the sum of the two angles A, E, is equal to two right angles; but the angle A is less than a right angle; therefore E, which is in a segment less than a semi-circle, is greater than a right angle.

THEOREM 38.

95. The angle BAE, contained by a tangent AE to a circle, and a chord AB, drawn from the point of contact, is equal to the angle AGB in the alternate segment.




Let the diameter ACF be drawn, and GF be joined; and, because the angles FGA, FAE, are right-angles (*theorems* 37, 30), and of these FGB, a part of the one, is equal to FAB, a part of the other, (*theorem* 35,) the remainders BAE, BAG, are equal.

# ALGEBRA.

96. ALGEBRA is a method of demonstrating propositions, and resolving questions, by means of the letters of the alphabet used as symbols.

LETTERS are employed to denote angles, lines, surfaces, or solids; each being considered as a multitude of units of the kind to which it belongs; and, consequently, as *number*, abstracted from figure. Thus, a letter may denote the number 3, or a line of five equal parts of any measure; as inches, yards, miles, &c. and so on.

Letters which are thus generally employed are called *quantities;* they being the *representation of quantities.*

It frequently happens that a quantity consists of several quantities of the same kind, as of two or more distances to make one distance; these must, therefore, be joined by addition, or by addition and subtraction. In order to indicate this junction, two distinct *signs* will be necessary.

The sign + *(plus)* implies that the quantity which follows it is to be added to that which goes before, and that all the quantities, when more than one, are to be added together into one sum. Thus, $a+b$ shows that $b$ is to be added to $a$, or that $a$ and $b$ are to be added together.

Again $a+b+c+d$ implies that $b$ is to be added to $a$; $c$ to the sum of $a$ and $b$; $d$ to the sum of $a, b, c$.

The sign − *(minus)* placed between two quantities, denotes that the quantity which follows it is to be subtracted from that which precedes it.

Thus, $m-n$ denotes that the quantity represented by $n$ is to be subtracted from that represented by $m$. Suppose, for instance, that $m$ is 7, and $n$ 3: then $7-3$ will be 4. Therefore, $m-n$ denotes the remainder arising by subtracting $n$ from $m$.

Hence SUBTRACTION is an opposite operation to ADDITION; and, therefore, if any quantity be both added to and subtracted from the same quantity, the quantity thus added and subtracted may be taken away entirely, by which the expression will be in its most simple form: thus $m+a-a$ is equivalent to $m$.

When two quantities are equal to each other, this equality is implied by the interposition of the double bar = between each of the quantities. Thus, $m+a-a=m$; as, also, $4+3+6-2=11$. Equal quantities, thus connected, are called *Equations.*

TERMS are all those parts of an expression that are separated by the signs of Addition and Subtraction.

Thus, $a+b+c-d$, is a quantity consisting of four *terms.*

Quantities which contain two terms are called *binomials:* thus, $a+b$, or $a-b$, are binomials.

The MULTIPLICATION of two or more factors is indicated by connecting the letters representing the factors; as, $ab$ denotes a product of two factors, $abx$ a

product of the three factors, $a$, $b$, and $x$. Thus, let $a=2$, $b=3$, and $x=5$; then $abx=30$: Again $mmmm$ signify a product of four factors, of which all are equal: suppose $m=2$, then $mmmm=16$.

When any number of factors are equal to each other, instead of repeating them to that number in the representation of the product, the product will be indicated with less trouble by writing only one of the equal factors and a digit; the latter containing as many units as the factors are in number, over the right-hand side of the factor so written. Thus, instead of $aa$, $bbb$, $xx$, $xxx$, the same idea will be more conveniently expressed thus, $a^2$, $b^3$, $x^2$, $x^3$.

The continued product of equal quantities is called a *Power;* the quantity itself is called the *Base* of that power; and the digit, which indicates the number of factors, is called the *Index* or *Exponent* of that power.

When factors of a product consist of compound terms, each compound factor is enclosed within brackets, or parentheses, and the factors thus included are joined to each other by bringing the bracket on the left hand of the one nearly close to that on the right-hand of the other.

Thus, the product of $a+b+c$, $x+a+c+d$, and $a+x$, is represented by $(a+b+c)(x+a+c+d)(a+x)$. Let $a=1$, $b=2$, $c=3$, $d=4$, and $x=5$, then will $(a+b+c)(x+a+c+d)(a+x)=(1+2+3)(5+1+3+4)(1+5)=468$.

Any Power of a compound quantity is represented in a similar manner to that of representing a simple quantity, by inclosing the compound within brackets, and writing the number which indicates the power over the right-hand bracket, and on the right-hand side of that bracket: thus, $(a+b)^3$ denotes the cube of $a+b$, and $(x+y+z)^4$ denotes the fourth power of $x+y+z$.

Division is represented by placing the dividend above the divisor, with a short line between them, as $\frac{a}{b}$; which expression shows how often the quantity $a$ contains the quantity $b$; or how often the dividend contains the divisor. Let $a$ be 12, and $b$ be 3, then $\frac{a}{b}$ will be 4.

Fractions are represented in the same manner as Division, by placing the numerator above and the denominator below a short line. Thus, $\frac{m}{n}$ indicates a fraction, whose numerator is $m$, and denominator $n$. Let $m$ be equal to 2, and $n$ equal to 3; then $\frac{m}{n}$ is equivalent to $\frac{2}{3}$ or two-thirds: or, if we suppose

$m$ to be equal to 17, and $n$ equal to 5, then $\frac{m}{n}$ would be 17-fifths of unity, or by dividing the numerator $m$, which is equivalent to 17, by the denominator $n$, which is equivalent to 5: the quotient will be 3 and $\frac{2}{5}$.

All expressions of quantity are said to be *Simple* when the operations are indicated by one or more letters, either in Multiplication or Division, without the intervention of the signs $+$ or $-$, as in the following: $a, ab, \frac{a}{b}, \frac{ab}{c}$; which are all *Simple* expressions.

*Known quantities* are generally represented by the initial letters, $a, b, c$, &c. of the alphabet, or by numbers; and the *unknown* quantities by the final letters, $v, w, x, y, z$.

*A Co-efficient* is the number prefixed to any quantity. Thus, in the expression $5x$, the number 5 is the co-efficient of $x$; or, if $x$ represent a quantity to be discovered by an operation, and $a$ a quantity already known, then, in the expression $ax$, the quantity $a$ is called the co-efficient of $x$.

Having explained the forms which indicate the operations of Simple Quantities, we shall now explain the rules for those performed upon Compounds.

## ADDITION OF ALGEBRA.

97. To add any number of simple affirmative quantities, which are of the same kind, together, or any number of quantities that have a common factor:

Prefix the sum of the co-efficients to the quantity, and the product will represent the sum; observing that, when no co-efficient is written, the co-efficient is understood to be unity: and, when the co-efficients are expressed by letters, these letters are to be joined with the sign $+$ within brackets, and the common quantity adjoined or subjoined.

In the following examples let the sum be put equal to S.

*Example* 1.—Add $a, a, a, a, a$, together; then $5a = S$

*Example* 2,—Add $ax$, $2ax$, $3ax$, together; then $6ax = S$.

*Ex*. 3.—Add $ax, bx, cx, dx, ex, fx$, togther; then $(a+b+c+d+e+f)x = S$.

98. To add any number of simple affirmative quantities of different kinds together:

Connect the whole to be added by the sign + ; and, if two or more of these quantities are to be found, of the same kind, they must be united into one simple quantity, or term, as above.

*Example* 1.—Add $a, b, c, d,$ together; then $a+b+c+d=\text{S}$.

*Example* 2.—Add $a, b, b, c, b, dx, ey,$ together; $a+3b+c+dx+ey=\text{S}$.

99. To add quantities together which have different signs:

Join all the quantities into one expression for the sum; observing to prefix the same sign to each quantity that it had before the whole were united.

*Example.*—Add $a, -bx, cd, -2bx,$ together; then, $a+cd-3bx=\text{S}$.

100. To add Compound Quantities together:

Connect all the quantities, in the several parts, to be added into one expression, giving each quantity the same sign that it had before, in each separate part, and observing to unite such terms as may be found of the same kind.

*Example.*—Add $5bx+\frac{4c}{2}$, $5ab-\frac{bc}{e}$, $2bx-3ab+3ex$, together. The answer will be $7bx+2ab+\frac{4c}{2}-\frac{bc}{e}+3ex=\text{S}$.

## SUBTRACTION OF ALGEBRA.

101. To subtract one simple quantity from another:

Join the quantity to be subtracted to that from which the subtraction is to be made, with a different sign to the original one. Let the difference be put equal to D.

*Example* 1.—Subtract $n$ from $m$; then $m-n=\text{D}$.

*Example* 2.—Subtract $3ab$ from $7ab$; then $7ab-3ab=4ab=\text{D}$.

102. To subtract a compound quantity either from a simple or compound quantity.

Subjoin the terms of the quantity to be taken away, with their signs changed, to that from which they are to be taken; observing that, when two terms are of the same kind, they must be united.

*Ex.*—From $xy+4b-3c$, subtract $bx-5b+4c$; then $xy+9b-7c-bx=\text{D}$.

It is evident that changing the signs of the terms of the quantity to be taken away cannot affect its aggregate or value, considered independently of

its signs. For, if they are of different kinds, the difference must be the same after the change as before it took place.

Thus, let $5-2+7-3$, be a quantity to be subtracted.

$$\text{Then} \quad 5-2+7-3=7$$
$$\text{and} \quad -5+2-7+3=-7$$

Hence we see the reason for changing the signs of the quantity to be subtracted.

## MULTIPLICATION OF ALGEBRA.

103. To find the algebraic product of two compound factors, or of one simple and the other compound.

If one of the factors be a simple quantity, let that factor be made the multiplier; then join the multiplier to every term of the multiplicand, and prefix the sign + to each product when its factors have like signs; but prefix the sign − when its factors have unlike signs; then the sum of all the products is the total product.

If the multiplier consist of more than one term, proceed with every term of the multiplier in the same manner as if it had but one term; then the sum of all the simple products is the whole product; observing that, all such simple products, as have a common factor, may be united together.

*Example* 1.—Multiply $a+b$ by $a+b$.

*Operation* . . .
$$\begin{array}{l} a+b \\ \underline{a+b} \\ a^2+ab \\ \underline{\quad +ab+b^2} \\ a^2+2ab+b^2=(a+b)^2 \end{array}$$

104. So that the square of any binomial consists of the square of each part and twice their product.

Hence, if we see such a quantity as $x^2+2ax+a^2$, we shall immediately know that it is the square of the binomial $x+a$.

*Example* 2.—Multiply $a-b$ by $a-b$, or find the square of $a-b$.

$$\begin{array}{ll} \textit{Operation}\ldots & a-b \\ & \underline{a-b} \\ & a^2-ab \\ & \underline{\quad -ab+b^2} \\ & a^2-2ab+b^2=(a-b)^2 \end{array}$$

105. Hence the square of any binomial, which has one of its parts negative, is the same which ever of the parts be negative; for the square of each of the parts is always affirmative, and twice the product of the two parts is negative; so that the square of $a-b$ is the very same as the square of $b-a$.

*Example* 3.—Multiply $a+b$ by $a-b$.

$$\begin{array}{ll} \textit{Operation}\ldots & a+b \\ & \underline{a-b} \\ & a^2+ab \\ & \underline{\quad -ab-b^2} \\ & a^2 \quad * \; -b^2=(a+b)(a-b) \end{array}$$

106. Hence we shall always know, by bare inspection only, that the difference of two squares is the product of the sum and difference of the roots: hence $x^2-y^2=(x+y)(x-y)$, and, reciprocally, that the product of the sum and difference of any two quantities is equal to the difference of their squares.

Thus $(a+z)(a-z)=a^2-z^2$.

## ALGEBRAIC DIVISION AND FRACTIONS.

107. DIVISION is the converse of Multiplication; therefore, if the signs be alike in the divisor and dividend, the quotient will be affirmative; but if unlike, the quotient will be negative. The general rule is to place the dividend in the form of a numerator, and the divisor in that of a denominator: expunge like quantities from both, and divide the co-efficients by the greatest common measure.

*Example* 1.—Divide $3ab$ by $b$. . . . . . . . . $\frac{3ab}{b}=3a$

*Example* 2.—Divide $-abc$ by $-bc$ . . $\frac{-abc}{-3bc}=\frac{a}{3}$

*Example* 3.—Divide $4ac$ by $16ba$ . . . . $\frac{4ac}{16ba}=\frac{c}{4b}$

108. Powers of the same root are divided by subtracting their exponents.

*Example* 1.—Divide $b^3$ by $b^2$. . . . . . . . . $\frac{b^3}{b^2}=b$.

*Example* 2.—Divide $a^4b^3c^2$ by $a^2b^2$ . . . . $\frac{a^4b^3c^2}{a^2b^2}=a^2bc^2$.

109. A Fraction is multiplied by any quantity by joining it to the numerator; thus, the product of $r$ and $\frac{m}{n}$ is represented by $\frac{rm}{n}$, which is the product of $rm$ divided by $n$, or the number of times that the product $rm$ contains $n$.

Since the operation of division is opposite to that of multiplication, if a fraction be multiplied by a quantity equal to its denominator, both the denominator and the multiplier may be taken away from the result; thus, if $\frac{a}{b}$ be multiplied by $b$, the result is $\frac{ab}{b}$, which is equivalent to the quantity $a$ only.

110. The *Terms* of a fraction are its numerator and denominator.

If the terms of a fraction be equally multiplied, that is, multiplied by the same quantity, the value of that fraction will be the same as before; thus $\frac{a}{b}=\frac{ma}{mb}$: and, if the terms of a fraction be equally divided by the same quantity, the result will be equal to the original quantity.

## ALGEBRAIC EQUATIONS.

111. The *resolution of an equation* is the mode of finding the value of the unknown quantity, in terms of those which are given.

The principles of this resolution depend on the following axioms, which are similar to those already given at the beginning of the Geometry, in page 15.

1. If to each side of an equation the same quantity be added, the sums will be an equation still.

2. If from each side of an equation the same quantity be subtracted, the remainders will still be an equation.

3. If each side of an equation be multiplied by the same quantity, the products will be an equation.

4. If each side of an equation be divided by the same quantity, the quotients will still be an equation.

## OF PROPORTION.

112. Definition.—Four quantities are proportionals when the first contains some part of the second, as often as the third contains the like part of the fourth.

### THEOREM 39.

113. If four quantities, $a, b, c, d$, are proportionals, the product of the two extremes will be equal to the product of the two means.

Let the first, $a$, contain the $n$th part of the second $b$, $m$ times; then, by the definition, the third, $c$, will contain the $n$th part of $d$ also $m$ times; now the $n$th part of $b$ is $\frac{b}{n}$, and the $n$th part of $d$ is $\frac{d}{n}$; therefore $\frac{a}{\frac{b}{n}}=m$; and $\frac{c}{\frac{d}{n}}=m$; wherefore $\frac{a}{b}=\frac{c}{d}$. Multiply each side of this equation by $bd$, and $\frac{abd}{b}=\frac{bcd}{d}$; therefore, dividing the terms of the fraction on the first side by $b$, and the terms of the fraction on the second side by $d$, which are common, $ad=bc$.

### THEOREM 40.

114. If any equation consist of the product of two quantities on each side, and if the four factors be placed in a row, so that the two factors on either side may occupy the middle place of the four, and the other two each one of the extreme places; the four factors, thus taken in order, will be proportionals.

Let $ad=bc$: Now here are four different ways of taking out the quantities; but in which ever of these ways they are taken, we shall always have $ad=bc$, by multiplying the two extreme terms together, and the two middle terms together.

Let, therefore, $a, b, c, d$, be one of the four; then, since $ad=bc$, divide both sides by $bd$ and $\frac{ad}{bd}=\frac{bc}{bd}$; that is, $\frac{a}{b}=\frac{c}{d}$; now let $h$ be the common measure of $a$

and $b$, supposing $h$ contained in $a$, $m$ times, and in $b$, $n$ times; then $\frac{a}{b}=\frac{mh}{nh}=\frac{m}{n}$; therefore $\frac{a}{\frac{b}{n}}=m$; but $\frac{b}{n}$ is the $n$th part of $b$; therefore the $n$th part of $b$ is contained in $a$, $m$ times.

Again, let $c=mi$, and we shall have $\frac{mh}{nh}=\frac{mi}{d}$; wherefore, by this equation, $d=ni$; therefore $\frac{c}{d}=\frac{mi}{ni}=\frac{m}{n}$; and, consequently, $\frac{c}{\frac{d}{n}}=m$: wherefore, also, $c$ contains the $n$th part of $d$, $m$ times.

115. Corollary.—Hence, if two fractions are equal, the numerator of the one will be to its denominator, as the numerator of the other is to its denominator.

To indicate that four quantities, $a, b, c, d$, are proportionals, the sign : is placed between the first two and between the last two; and the sign :: is placed between the two terms that stand in the middle; thus, $a : b :: c : d$, is read, as $a$ is to $b$, so is $c$ to $d$.

116. Four proportionals are termed a *proportion*.

Of four proportional quantities, the last term is called the fourth proportional to the other three.

The first and third terms of a proportion are called the *antecedents*, and the second and fourth terms the *consequents*.

### SCHOLIUM.

117. Since, from $ad=bc$, we may choose four different ways of taking out the first term, in order to make a proportion; and since there are two ways of making choice of the second term after the first, there are eight ways in which the positions of the terms will be different: these are—

$$a : b :: c : d$$
$$a : c :: b : d$$
$$b : a :: d : c$$
$$b : d :: a : c$$
$$c : a :: d : b$$
$$c : d :: a : b$$
$$d : b :: c : a$$
$$d : c :: b : a$$

118. So that, in every two sets of proportionals, where the same quantity stands first, the terms of the one set are placed alternately to those of the other; and we may also observe that, four of these sets of proportionals have their terms inverted with regard to the other four, and are therefore the same when read in contrary order.

### THEOREM 41.

119. If the corresponding terms of any number of proportions are multiplied together, the products, taken in the same order, will be proportionals.

$$\text{Thus, as } a : b :: c : d$$
$$e : f :: g : h$$
$$i : k :: l : m$$
$$\text{then, as } aei : bfk :: cgl : dhm$$
$$\text{For } ad = bc$$
$$eh = fg$$
$$im = kl$$
$$\text{therefore, } adehim = bcfgkl.$$

Consequently, $aei : bfk :: cgl : dhm$; therefore the proposition is manifest.

120. Corollary.—Hence, if the proportions are the same as the first, we shall have $a^3 : b^3 :: c^3 : d^3$.

121. The proportion which is formed by the multiplication of the corresponding terms of two or more proportions is said to be compounded of these proportions.

When two of the proportions to be compounded are the same, the proportion compounded of the two is said to be the duplicate of either: thus, $a^2 : b^2 :: c^2 : d^2$ is in duplicate proportion to that of $a : b :: c : d$.

When three proportionals, which are the same, are compounded, the compound is said to be triplicate to either of the simple ones: thus, $a^3 : b^3 :: c^3 : d^3$, is the triplicate proportion of $a : b :: c : d$.

And so on to the succeeding orders.

### THEOREM 42.

122. If four quantities, $a, b, c, d$, be proportionals, the first will be to the sum of the first and second as the third is to the sum of the third and fourth.

For, since $a, b, c, d$, are proportionals, $ad=bc$. To each side of this equation add the product $ac$, and we have $ad+ac=bc+ac$; that is, $a(c+d)=c(a+b)$.

$$\text{Therefore, } a : a+b :: c : c+d.$$

123. Corollary.—Since out of the two equal products $ad$, $bc$, four combinations in twos may be chosen, viz.

$$ab,\ ac,\ bd,\ cd,$$

we may therefore have the four following equations all different, by adding each combination to each side of the equation $ad=bc$, viz.

$$\begin{aligned} \text{No. } 1 \ldots\ldots a(c+d) &= c(a+b) \\ 2 \ldots\ldots a(b+d) &= b(a+c) \\ 3 \ldots\ldots d(a+b) &= b(c+d) \\ 4 \ldots\ldots d(a+c) &= c(b+d) \end{aligned}$$

Since each of these equations will give eight sets of proportionals; therefore the whole four will give thirty-two.

### THEOREM 43.

124. If four quantities, $a, b, c, d$, be proportionals, as the first is to the difference of the first and second, so is the third to the difference of the third and fourth.

For, since $a, b, c, d$, are proportionals, $ad=bc$. Subtract each side of this equation from the product $ac$, and we have $ac-ad=ac-bc$; that is, $a(c-d)=c(a-b)$, whence $a : a-b :: c : c-d$.

125. Corollary.—Since out of the two equal products $ad$, $bc$, we may choose the four combinations in twos, viz. $ab$, $ac$, $bd$, $cd$; and may therefore have the four following equations, by subtracting each side of the original equation, $ad=bc$, from each combination.

$$\text{No. } 1 \ldots a(c-d)=c(a-b)$$
$$2 \ldots a(b-d)=b(a-c)$$
$$3 \ldots d(b-a)=b(d-c)$$
$$4 \ldots d(c-a)=c(d-b)$$

126. Again, by subtracting each of the products, $ab$, $ac$, $bd$, $cd$, from each side of the original equation, $ad=bc$, we have—

$$\text{No. } 1 \ldots a(d-c)=c(b-a)$$
$$2 \ldots a(d-b)=b(c-a)$$
$$3 \ldots d(a-b)=b(c-d)$$
$$4 \ldots d(a-c)=c(b-d)$$

Now, since every one of these eight different equations will give eight sets of proportionals, in each set of which the situations of the terms will be varied; therefore the whole will give sixty-four sets of proportionals, in which the terms will have different situations in every two sets.

### THEOREM 44.

127. If four quantities, $a, b, c, d$, be proportionals, it will be as the sum of the first and second is to their difference, so is the sum of the third and fourth to their difference.

For, dividing the equation, No. 3, pr. 123, by the equation, No. 3, pr. 126, we shall have—

$$\frac{a+b}{a-b}=\frac{c+d}{c-d}$$

And, by dividing the equation, No. 3, in pr. 123, by the equation, No. 3, in pr. 125, we have,

$$\frac{a+b}{b-a}=\frac{c+d}{d-c}$$

Wherefore $a+b : a \sim b :: c+d : c \backsim d$*

128. Three quantities are said to be proportionals when the first is to the middle quantity as the middle quantity is to the third: thus, let $a, b, c$, be three proportionals; then $a : b :: b : c$.

* The character $\sim$ between two quantities signifies the difference, as $5 \backsim 9=4$.

### THEOREM 45.

129. If three quantities be proportionals, the product of the two extremes is equal to the square of the mean.

Let $a, b, c$, be the three proportionals; then, $ac=b^2$, for, since $\frac{b}{a}=\frac{c}{b}$, multiply both sides of this equation by $ab$, and $\frac{ab^2}{a}=\frac{abc}{b}$, that is, $b^2=ac$.

### THEOREM 46.

130. If the first and second terms of two proportions are alike, the third and fourth terms of both, placed in the order of their antecedents and consequents, will be proportionals.

Let $a:b::c:d$, and $a:b::e:f$; then will $c:d::e:f$. From the first proportion we have $ad=bc$, and from the second we have $be=af$; therefore, multiplying the corresponding sides of these equations, we have $adbe=bcaf$; and, throwing out the common factors on each side of this equation, there will remain $de=cf$; wherefore, $c:d::e:f$.

### THEOREM 47.

131. In any number of proportionals, of which all the ratios are equal, it will be, as the antecedent of any ratio is to its consequent, so is the sum of all the antecedents of the other ratios to the sum of all the consequents.

For, let $\frac{a}{b}=\frac{c}{d}, \frac{c}{d}=\frac{e}{f}, \frac{e}{f}=\frac{g}{h}$, then will $\frac{a}{b}=\frac{c}{d}=\frac{e}{f}=\frac{g}{h}$.

$$\text{Therefore, } ad=bc$$
$$af=be$$
$$ah=bg$$
$$\text{Whence } a(d+f+h)=b(c+e+g)$$

Wherefore, $a:b::c+e+g:d+f+h$, as was to be shown.

# GEOMETRY, CONTINUED.

Having now explained so much of the principles of Algebra and Proportion as may be requisite to elucidate the subsequent propositions, we again proceed with the Elements of Geometry. The geometric definitions, &c. have been given, generally, in pages 10 to 14; but to those already explained are to be added several which follow, as it now becomes necessary that they, also, should be known.

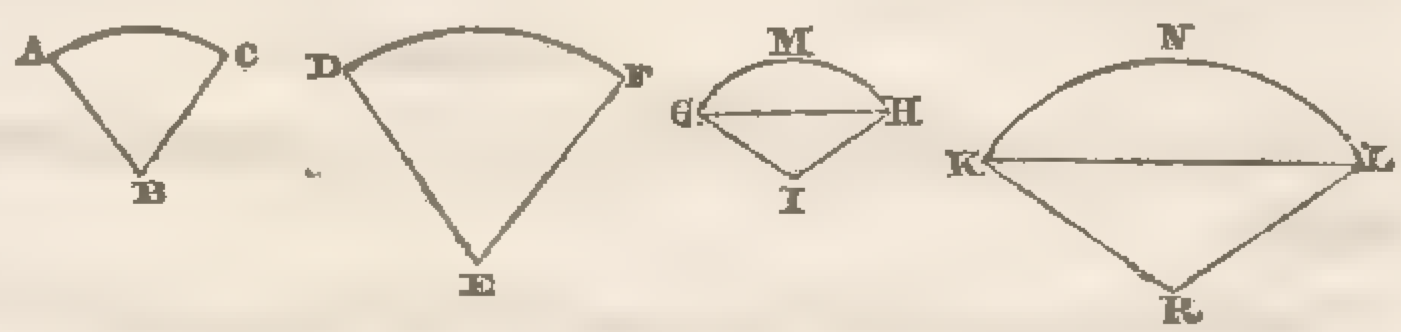
132. Equivalent Figures are such as have equal surfaces, without regard to their form.

133. Identical Figures are such as would entirely coincide, if the one be applied to the other.

134. In Equiangular Figures, the sides which contain the equal angles, and which adjoin equal angles, are *homologous.*

135. Two figures are *similar,* when the angles of the one are equal to the angles of the other, each to each, and the homologous sides are proportionals.

136. In two Circles, similar sectors, similar arcs, or similar segments, are those which have equal angles at the centre.

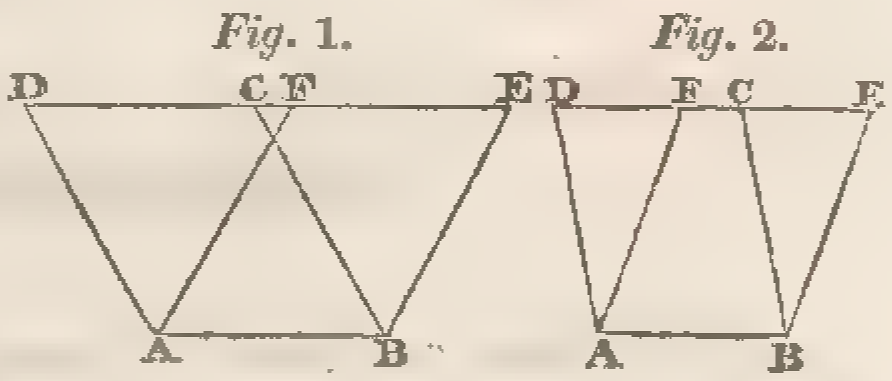



Thus, if the sector ABC be similar to the sector DEF, then the angle ABC will be equal to the angle DEF; or, if the arc AC be similar to the arc DF, then the angle at B will be equal to the angle at E. Also, if the segment GMH be similar to the segment KNL, the angle I will be equal to the angle R.

137. The Area of a figure is the quantity of surface, containing a certain number of units of any given scale; as of inches, feet, yards, &c.

THEOREM 48.

138. Parallelograms which have equal bases and equal altitudes are equal.



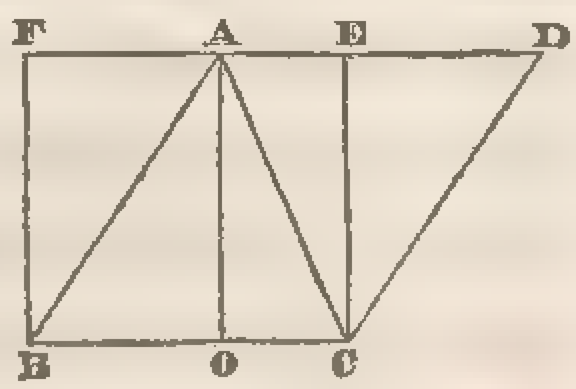

Take the two parallelograms, ABCD, and ABEF, upon the same base, AB, and between the same parallels, AB and DE; these parallelograms are equal.

For, in the parallelogram ABCD (*fig.* 1), the opposite sides CD and AB are equal; and in the parallelogram ABEF, the opposite sides EF and AB are equal; therefore EF is equal to CD (84)*. Again, in the parallelogram ABCD (*fig.* 2), the side CD is equal to AB; and in the parallelogram ABEF, the side FE is equal to AB; therefore EF is equal to CD. Now, in *fig.* 1, since CD is equal to EF, add CF to both; then will DF be equal to CE. In *fig.* 2, take away the common part CF, and there will remain DF equal to CE. Therefore, in each of these figures, the three straight lines AD, DF, FA, are respectively equal to the three straight lines BC, CE, EB; and, consequently, the triangle ADF is equal to the triangle BCE; therefore, from the quadrilateral ABED take away the triangle BCE, there will remain the parallelogram ABCD; and, from the same quadrilateral, take away the equal triangle ADF, and there will remain the parallelogram ABEF: therefore the parallelogram ABCD is equal to the parallelogram ABEF.

139. Corollary.—Every parallelogram is equal to a rectangle, of the same base and altitude.

THEOREM 49.

140. Any triangle is equal to half a parallelogram of the same base and altitude.




For the triangle ABC is equal to the triangle ACD, and the parallelogram ABCD is equal to the sum of both triangles; and, consequently, double to one of them.

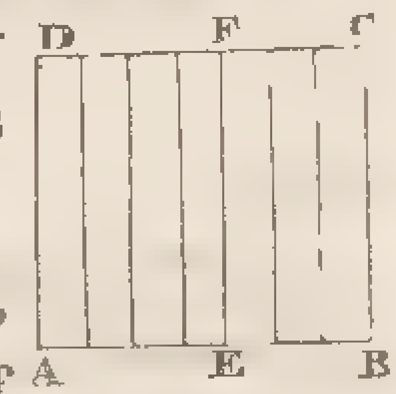
* The figures thus inserted in a parenthesis refer to a preceding or a following paragraph; as, in this instance, to 84, on page 29.

141. Corollary 1.—Hence every triangle is half a rectangle, having the same base and altitude.

142. Corollary 2.—Triangles which have equal bases and equal altitudes are equal.

### THEOREM 50.

143. Rectangles, of the same altitude, are to one another as their bases.

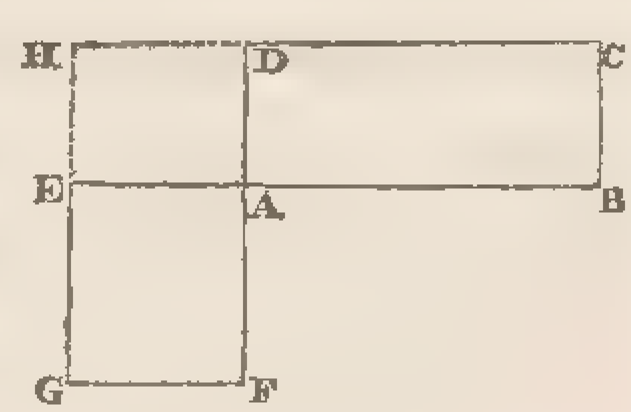



Let ABCD, AEFD, be two rectangles, which have a common altitude AD; they are to one another as their bases AB, AE.

For, suppose that the base AB contains seven equal parts, and that the base AE contains four similar parts; then, if AB be divided into seven equal parts, AE will contain four of them. At each point of division draw a perpendicular to the base, and these will divide the figure ABCD into seven equal rectangles (138); and, as AB contains seven such parts as AE contains four, the rectangle ABCD will also contain seven such parts as the rectangle AEFD contains four; therefore the bases AB, AE, have the same ratio that the rectangles ABCD, AEFG, have.

### THEOREM 51.

144. Rectangles are to one another as the products of the numbers which express their bases and altitudes.




Let ABCD, AEGF, be two rectangles, and let some line taken, as a unit, be contained $m$ times in AB, the base of the one, and $n$ times in AD, its altitude; also $p$ times in AE, the base of the other, and $q$ times in AF, its altitude; the rectangle ABCD shall be to the rectangle AEGF, as the product $mn$ is to the product $pq$.

Let the rectangles be so placed that their bases AB, AE, may be in a straight line; then their altitudes AD, AF, shall also form a straight line (48). Complete the rectangle EADH; and, because this rectangle has the same alti-

tude as the rectangle ABCD, when EA and AB are taken as their bases; and the same altitude as the rectangle AEGF, when AD, AF, are taken as their bases; we have the rectangle ABCD : ADHE :: AB : AE :: $m : p$ ...(143)

But........ $m : p :: mn : pn$

therefore, ABCD : ADHE :: $mn : pn$.

In like manner, ADHE : AEGF :: $pn : pq$

But, placing the terms of these two sets of proportionals alternately, we have,

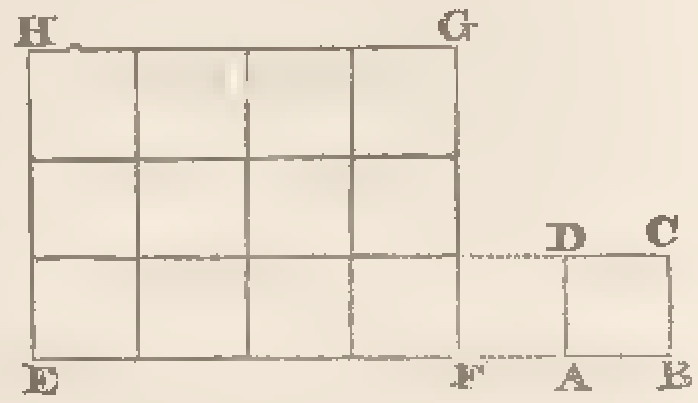
ADHE : $pn$ :: ABCD : $mn$

and.............. ADHE : $pn$ :: AEGF : $pq$

therefore, by equality, ABCD : $mn$ :: AEGF : $pq$

therefore, alternately, ABCD : AEGF :: $mn : pq$.

145. Observation.—If ABCD, one of the rectangles, be a square, having the measuring unit for its side; this square may be taken as the measuring unit of its surfaces; because the linear unit, AB, is contained $p$ times in EF, and $q$ times in EH, by the proposition.




$1 \times 1 : pq ::$ ABCD : EFGH.

Hence the rectangle EFGH will contain the superficial unit ABCD, as often as the numeral product $pq$ contains unity.

Consequently, the product $pq$ will express the area of the rectangle, or will indicate how often it contains the unit of its surfaces.

Thus, if EF contains the linear unit AB four times, and EH contains it three times, the area EFGH will be $3 \times 4 = 12$: that is, equal to twelve times a square whose side AB is $= 1$.

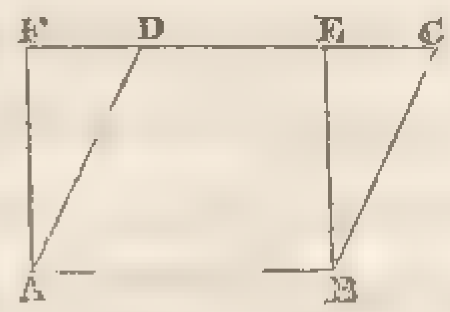
In consequence of the surface of the rectangle EFGH being expressed by the product of its sides, the rectangle, or its area, may be denoted by the symbol EF $\times$ FG, in conformity to the manner of expressing a product in arithmetic.

However, instead of expressing the area of a square, made on a line AB, thus, AB $\times$ AB; it is thus expressed $AB^2$.

146. NOTE.—A rectangle is said to be contained by two of its sides, about any one of its angles.

THEOREM 52.

147. The area of a parallelogram is equal to the product of its base and altitude.



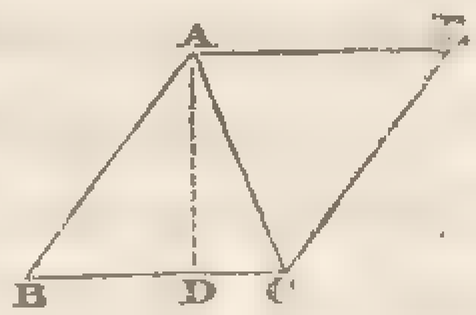

For the parallelogram ABCD is equal to the rectangle ABEF, which has the same base AB, and the same altitude (138), and this last is measured by AB × BE, or by AB × AF; that is, the product of the base of the parallelogram and its altitude.

148. COROLLARY.—Parallelograms of the same base are to one another as their altitudes; and parallelograms of the same altitudes are to one another as their bases.

For, in the former case, put B for their common base, and A, $a$, for their altitudes; then we have $B \times A : B \times a :: A : a$. And, in the latter case, put A for their common altitude, and B, $b$, for their bases; then $B \times A : b \times A :: B : b$.

THEOREM 53.

149. The area of a triangle is equal to the product of the base by half its altitude.

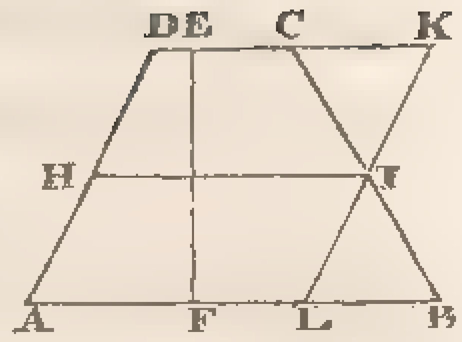



For the triangle ABC is half the parallelogram ABCE, which has the same base, BC, and the same altitude AD (140); but the area of the parallelogram is BC × AD (147), therefore, the area of the triangle is $\frac{1}{2}$BC × AD, or BC × $\frac{1}{2}$AD.

150. COROLLARY.—Two triangles of the same base are to one another as their altitudes; and two triangles, of the same altitude, are to one another as their bases.

THEOREM 54.

151. The area of every trapezoid, ABCD, is equal to the product of half the sum of its parallel sides, AB, DC, by its altitude, EF.



Through I, the middle of the side BC, draw KL, parallel to the opposite side AD, and produce DC until it meet KL in K. In the triangles IBL, ICK, the side IB is equal to IC, and the angle B equal to C (74), the angle BIL equal to CIK; therefore the triangles are equal (54), and the side CK equal to BL. Now the parallelogram ALKD is the sum of the polygon ALICD; and the triangle CIK, and the trapezoid ABCD, is the sum of the same polygon and the triangle BIL; therefore, the trapezoid ABCD is equal to the parallelogram ALKD, and has, for its measure, AL × EF. Now AL is equal to DK, and BL equal to CK; and CD = DK − CK; but DK is equal to AL, and CK equal to BL;

$$\text{Therefore } CD = AL - BL.$$

$$\text{But} \ldots\ldots AB = AL + BL.$$

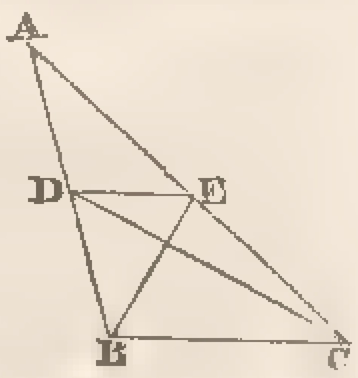
$$\text{Therefore, } AB + CD = 2AL$$

$$\text{Consequently } \tfrac{1}{2}(AB+CD) = AL.$$

$$\text{It follows that} \ldots AL \times EF = \tfrac{1}{2}(AB + CD) \times EF.$$

THEOREM 55.

152. A straight line, DE, drawn parallel to the side of a triangle ABC, divides the other sides AB, AC, proportionally, or so that AD : DB :: AE : EC.



Join BE and DC: the two triangles BDE, CDE, have the same base, DE, and they have also the same altitude; because BC is parallel to DE; and, consequently, the triangles DBE and DCE are equal. Since the triangles BED and AED have the same altitude, they are to one another as their bases; and since the triangles CED and AED have the same altitude, they are to one another as their bases.

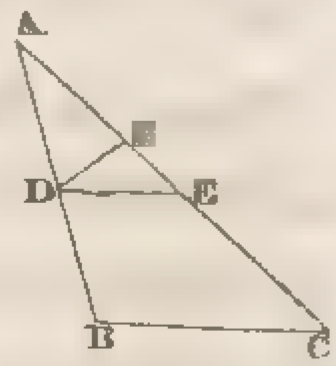
Therefore, the triangle BDE : ADE :: BD : DA. But since the triangle BDE is equal to the triangle CED, therefore the triangle CED : ADE :: BD : DA.

But the triangle CED : ADE :: CE : EA.

It follows that, BD : DA :: CE : EA.

THEOREM 56.

153. If the two sides, AB, AC, of a triangle be cut proportionally by the line DE, so that AD : DB :: AE : EC, the line DE shall be parallel to the remaining side of the triangle.




For, if DE be not parallel to BC, some other line, DO, will be parallel to BC; then, by the preceding proposition,

AD : DB :: AO : OC.

And, by hypothesis, AD : DB :: AE : EC.

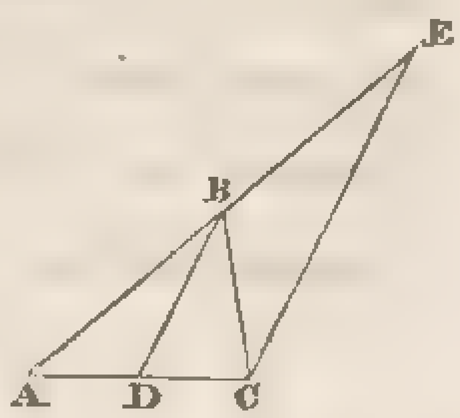
Therefore, ...... AO : OC :: AE : EC.

And, by addition, AC : OC :: AC : EC.

And hence OC must be equal to EC; which is impossible, unless the point O coincide with E; therefore no line besides DE can be parallel to BC.

THEOREM 57.

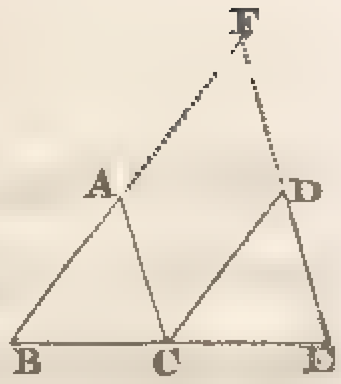
154. A line, BD, which bisects any angle, ABC, of a triangle, will divide the opposite side AC into two segments, AD, DC, which shall have the same ratio as the other two sides, AB, BC, of the triangle.




From C, one extremity of the base, draw CE, parallel to BD, meeting AB produced in E. Then the angle ABD is equal to the angle BEC (75), and the angle CBD equal to BCE (74); but, by hypothesis, the angle ABD is equal to CBD; therefore the angle BEC is equal to BCE: hence the side BC is equal to BE (63). Now, because ACE is a triangle, and BD is drawn parallel to one of its sides, AD : DC :: AB : BE (152): but, since BE is equal to BC; therefore AD : DC :: AB : BC.

THEOREM 58.

155. Two equiangular triangles have their sides proportional, and are similar to each other.




Let ABC, DCE, be two triangles, which have their angles equal, each to each; viz. BAC equal to CDE, ABC equal to DCE, and ACB equal to DEC; the homologous sides, or the sides adjacent to the equal angles, shall be proportionals; that is, BC : CE :: BA : CD, and BA : CD :: AC : DE.

Place the homologous sides BC, CE, in a straight line; and, because the angles B and E are together less than two right angles, the lines BA and ED shall meet, if produced (76): let them meet in F. Then, since BCE is a straight line, and the angle BCA equal to E, AC is parallel to EF. In like manner, because the angle DCE is equal to B, the straight line CD is parallel to BF; therefore ACDF is a parallelogram.

156. In the triangle BFE, the straight line AC is parallel to FE; wherefore BC : CE :: BA : AF (152). Again, in the same triangle, BFE, CD is parallel to BF; therefore, BC : CE :: FD : DE; but, by substituting CD for its equal AF, in the first set of proportionals, and AC for its equal FD in the second set,

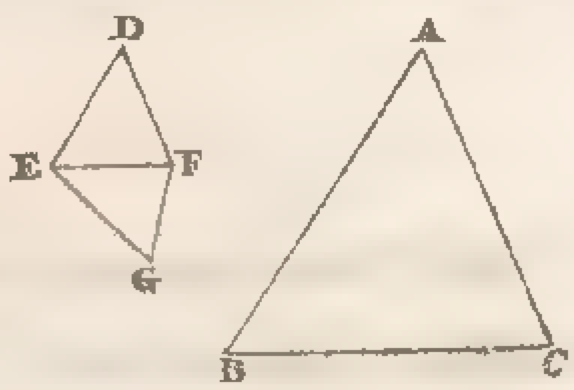
we have ............ BC : CE :: BA : CD by the first,
and ................. BC : CE :: AC : DE by the second,
therefore, by equality, BA : CD :: AC : DE;

therefore the homologous sides are proportionals; and, because the triangles are equiangular, they are similar.

Scholium.—It may be remarked that the homologous sides are opposite to the equal angles.

### THEOREM 59.

157. Two triangles, which have their homologous sides proportionals, are equiangular and similar.




Suppose that BC : EF :: AB : DE
and that.... AB : DE :: AC : DF

the triangles ABC, DEF, have their angles equal: viz. A equal to D, B equal to E, and C equal to F. At the point E make the angle FEG equal to B, and at the

point F make the angle EFG equal to C, then G shall be equal to A (80), and the triangles GEF, ABC, shall be equiangular; therefore,

by the preceding prop. BC : EF :: AB : EG

and, by hypothesis, .. BC : EF :: AB : DE; therefore EG is equal to DE.

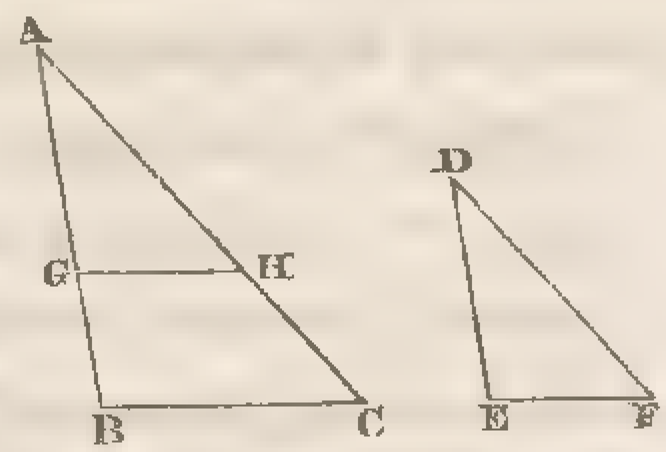
In like manner. ....... BC : EF :: AC : FG

and, by hypothesis, .. BC : EF :: AC : DF; therefore FG is equal to DF.

Thus, it appears that, the triangles DEF, GEF, have their three sides equal, each to each, therefore they are equal (58). But, by construction, the triangle GEF is equiangular to the triangle ABC; therefore, also, the triangles DEF, ABC, are equiangular and similar.

### THEOREM 60.

158. Two triangles which have an angle of the one equal to an angle of the other, and the sides about them proportionals, are similar.




Let the angle A equal D, and suppose that AB : DE :: AC : DF, the triangle ABC is similar to DEF.

Take AG equal to DE, and draw GH parallel to BC, the angle AGH shall be equal to ABC (75), and the triangle AGH equiangular to the triangle ABC; therefore AB : AG :: AC : AH; but AG is equal to DE;

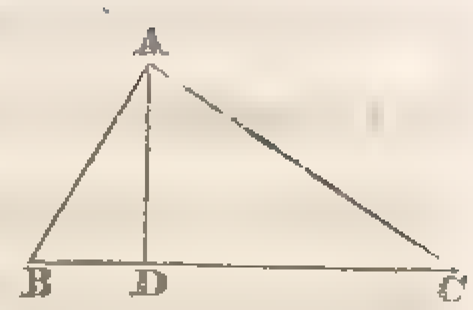
therefore ........ AB : DE :: AC : AH,

but, by hypothesis, AB : DE :: AC : DF; therefore AH is equal to DF. The two triangles AGH, DEF, have therefore an angle of the one equal to an angle of the other, and the sides containing these angles equal; therefore they are equal (53); but the triangle AGH is similar to ABC.

### THEOREM 61.

159. A perpendicular, AD, drawn from the right angle, A, of a right-angled triangle, upon the hypothenuse, or longest side, BC, will divide that triangle into two others, which will be similar to each other, and to the whole.

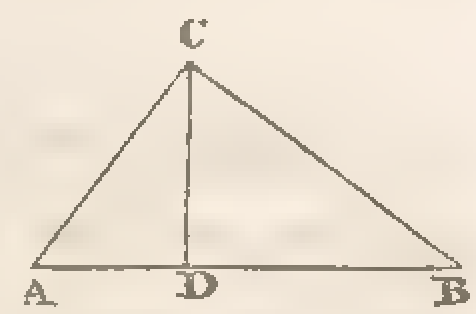
The triangles BAD and BAC have the common angle B; and, besides, the right angle BDA is equal to the right angle BAC; therefore, the third angle BAD of the one is equal to the third angle C of the other (80); therefore the two triangles are equiangular and similar. In like manner it may be demonstrated that the triangle DAC is equiangular and similar to the triangle BAC; therefore the three triangles are equiangular and similar to one another.




THEOREM 62.

160. The square described upon the hypothenuse, or longest side, is equal to the squares described upon the other two sides.

From the right angle C draw CD, perpendicular to the hypothenuse AB; then the triangle ABC is divided into two triangles, ADC, CDB, which are similar to one another, and to the whole triangle ABC (159);

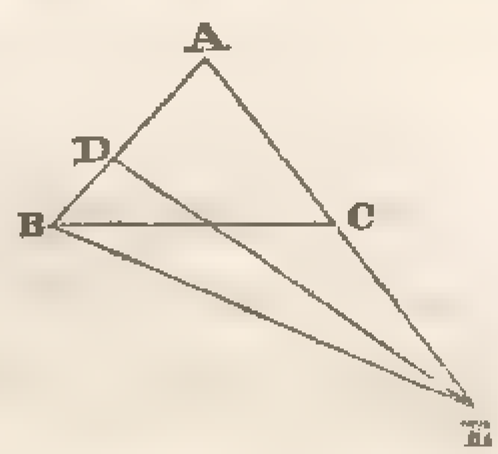



therefore, by the similar triangles, ABC, CBD, . . $AB : BC :: BC : BD$;
again, by the similar triangles, BAC, CAD . . $AB : AC :: AC : AD$;
therefore, reducing the first to an equation, . . . . $AB \times BD = BC^2$
and, reducing the second analogy to an equation, $AB \times AD = AC^2$
then, adding these two equations . . . . . . . . $AB \times (AD + BD) = AC^2 + BC^2$
but, since AB is equal to the sum of the two lines AD, DB, therefore $AB^2 = AC^2 + BC^2$.

THEOREM 63.

161. Two triangles, which have an angle of the one equal to an angle of the other, are to each other as the rectangle of the sides about the equal angles.

Suppose the two triangles joined, so as to have a common angle, and let the two triangles be ABC, ADE. Draw the straight line BE.



Now the triangle ABE : tria. ADE :: AB : AD;

Therefore the triangle ABE : tria. ADE :: AB × AE : AD × AE.

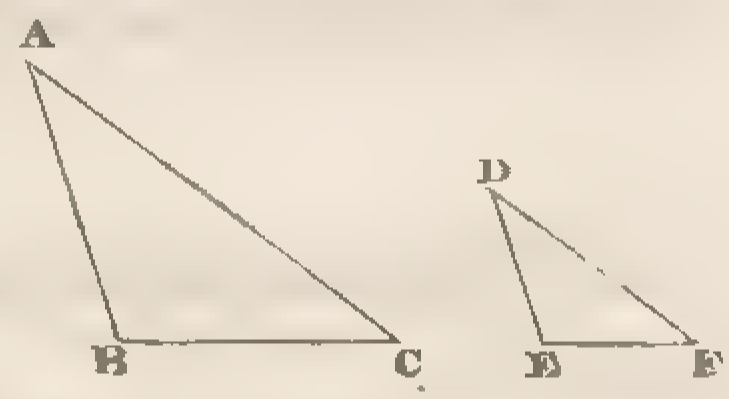
Or, alternately, the triangle ABE : AB × AE :: the triangle ADE : AD × AE.

In like manner, the triangle ABE : AB × AE :: the triangle ABC : AB × AC.

Therefore, by equality, the tria. ABC : tria. ADE :: AB × AC : AD × AE.

THEOREM 64.

162. Similar triangles are to one another as the squares of their homologous sides.




Let the angle A be equal to the angle D, and the angle B equal to E.

Then AB : DE :: AC : DF (155)

and AB : DE :: AB : DE.

therefore, by multiplying the corresponding terms, we have $AB^2 : DE^2$ :: AC × AB : DF × DE.

But the triangle BAC : triangle EDF :: AC × AB : DF × DE (162).

Therefore the triangle ABC : triangle DEF :: $AB^2 : DE^2$.

Or thus, let △ signify a triangle; then (162)—

△ ABC : △ DEF :: AB × AC : DE × DF.

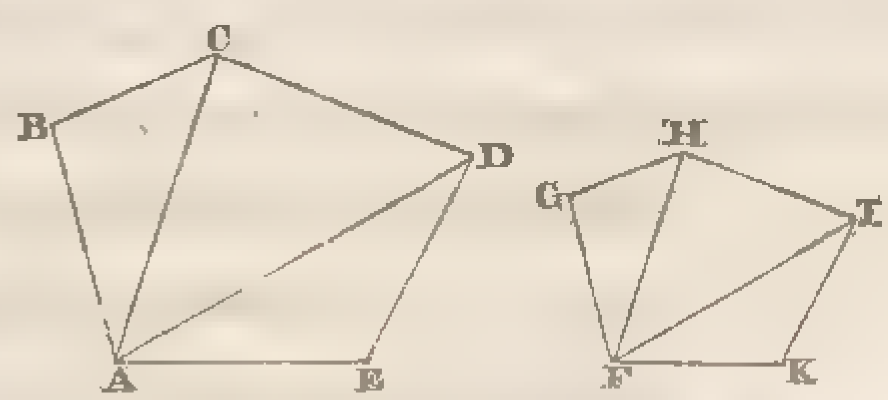
△ ABC : △ DEF :: AB × BC : DE × EF.

AC × BC : DF × EF :: △ ABC : △ DEF.

Therefore, by multiplication, △ ABC : △ DEF :: $AB^2$ : $DE^2$.

THEOREM 65.

163 Similar polygons are composed of the same number of triangles, which are similar, and similarly situated.




In the polygon ABCDE, draw from any angle, A, the diagonals AC, AD; and, in the other polygon, FGHIK, draw, in like manner, from the angle F, which is homologous to A, the diagonals, FH, FI.

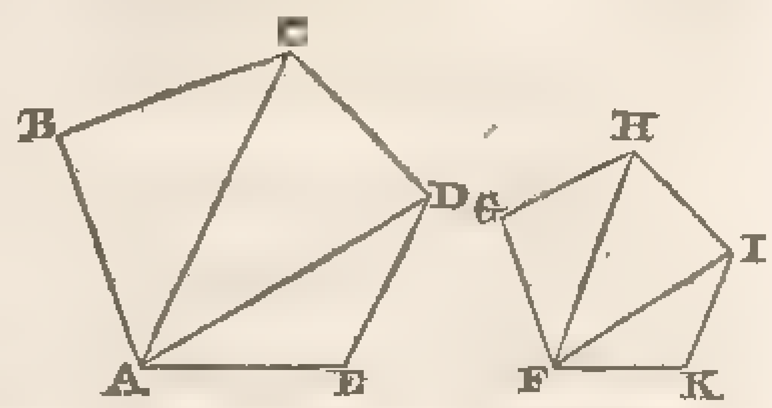
Since the polygons are similar, the angle B is equal to its homologous angle G; and, besides, AB : BC :: FG : GH; therefore, the triangles ABC and FGH

are similar (158), and the angle BCA is equal to GHF; these equal angles being taken from the equal angles BCD, GHI, the remainders ACD, FHI, are equal: but, since the triangles ABC and FGH are similar, we have AC : FH :: BC : GH; and, because of the similitude of the polygons, we have BC : GH :: CD : HI; therefore, AC : FH :: CD : HI. Now it has been shown that the angle ACD is equal to FHI; therefore the triangles ACD, FHI, are similar (158).

In like manner, it may be demonstrated that, the remaining triangles of the two polygons are similar; therefore the polygons are composed of the same number of similar triangles, similarly situated.

### THEOREM 66.

164. The perimeters of similar polygons are to one another as their homologous sides.



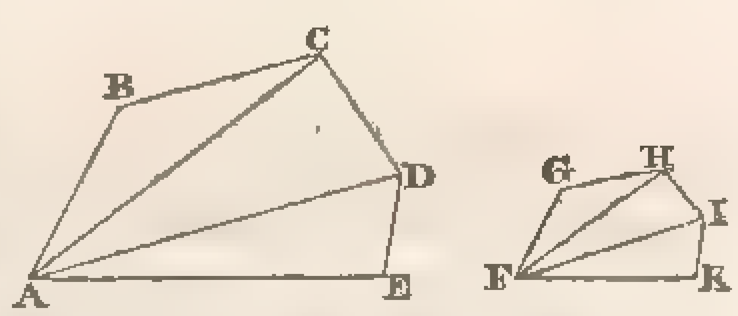

AB : FG :: BC : GH.

BC : GH :: CD : HI.

Therefore, AB : FG :: AB + BC + CD :: FG + GH + HI (131); wherefore AB is to FG as the perimeter of the polygon ABCD is to the perimeter of the polygon FGHIK.

### THEOREM 67.

165. The areas of similar polygons are as the squares of their homologous sides.




Let the polygons be ABCDE and FGHIK; from any angle, A, draw the diagonals AC, AD; and, from the homologous angle F, draw the diagonals FH, FI; then the triangles ABC, ACD, ADE, are respectively equal, and similar to the triangles FGH, FHI, FIK.

Therefore the triangle ABC : triangle FGH :: $AC^2$ : $FH^2$

And .... the triangle ACD : triangle FHI :: $AC^2$ : $FH^2$.

Therefore the triangle ABC : triangle FGH :: ACD : FHI.

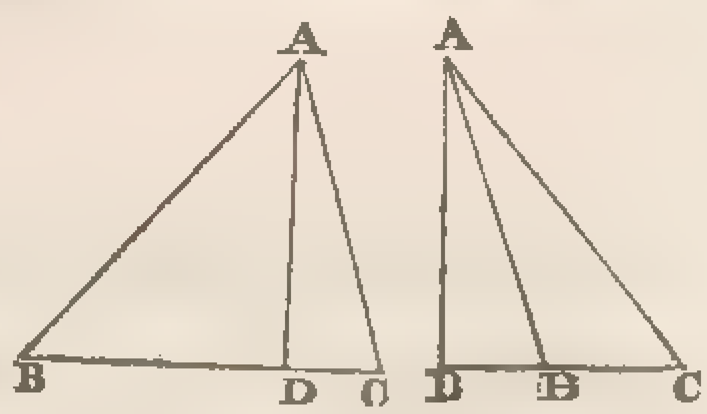
In the same manner it may be demonstrated that the triangle ACD : triangle FHI :: ADE : FIK, and so on, if the polygons consist of more triangles.

Hence (131) the triangle ABC is to the triangle FGH as the sum of the triangles ABC, ACD, ADE, to the sum of the triangles FGH, FHI, FIK; but the sum of the triangles ABC, ACD, ADE, compose the whole polygon ABCDE, and the sum of the triangles FGH, FHI, FIK, compose the polygon FGHIK; wherefore the triangle ABC is to the triangle FGH as the polygon ABCDE is to the polygon FGHIK; but the triangle ABC is to the triangle FGH as $AB^2$ is to $FG^2$; therefore the similar polygons are as the squares of their homologous sides.

166. Corollary.—If three similar figures have their homologous sides equal to the three sides of a right-angled triangle, the figure made on the side opposite to the right angle shall be equal to the other two.

### THEOREM 68.

167. In any triangle, ABC, the square of AB, opposite to one of the acute angles, is equal to the difference between the sum of the squares of the other two sides, and twice the rectangle $BD \times DC$, made by the perpendicular AD, to the side BC.




There are two cases, according as the perpendicular falls within or without the triangle. In the first case, $BD = BC - CD$; and, in the second case, $BD = CD - BC$.

In either case .............. $BD^2 = BC^2 + CD^2 - 2BC \times CD$.

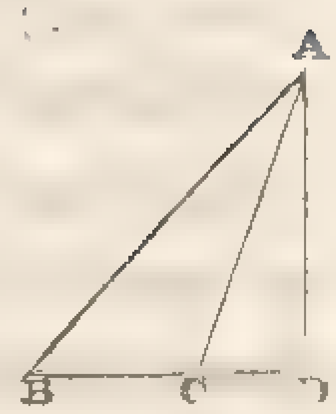
But (160)............ ..... $AB^2 = AD^2 + BD^2$

and (160) ............ $AD^2 + CD^2 = AC^2$.

Therefore, by addition, ...... $AB^2 = AC^2 + BC - 2B \times CD$.

### THEOREM 69.

168. In any obtuse-angled triangle, the square of the side opposite to the obtuse angle is equal to the sum of the squares of the other two sides, and twice the rectangle, $BC \times CD$, made by the perpendicular, AD, upon the side BC.



For ............ $BD = BC + CD$;

Therefore, ...... $BD^2 = BC^2 + CD^2 + 2BC \times CD$;

But, (160) ...... $AB^2 = AD^2 + BD^2$

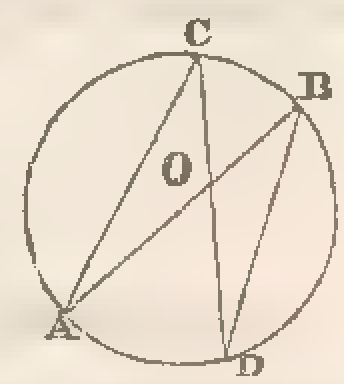
and (160) .. $AD^2 + CD^2 = AC^2$

Therefore, by adding these three equations together,

$$AB^2 = AC^2 + BC^2 + 2BC \times CD.$$

THEOREM 70.

169. If any two chords, in a circle, cut each other, the rectangle of the segments of the one is equal to the rectangle of the segments of the other.



Let AB and CD cut each other in O, then $OA \times OB = OD \times OC$.

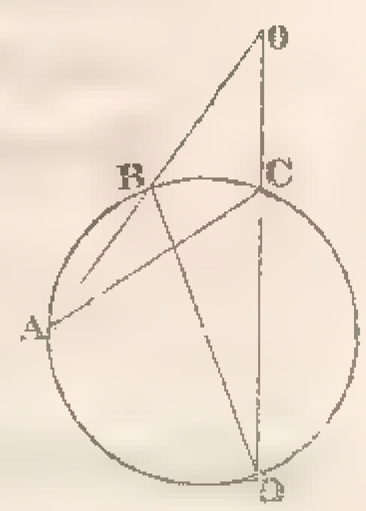
For, join AC and BD: then, in the triangles AOC, BOD, the vertical angles at O are equal; also the angle $A = D$ and $C = B$ (92), consequently the triangles AOC and DOB are similar, and their homologous sides proportional.

Whence $AO : OC :: DO : OB$

Wherefore $AO \times OB = OD \times CO$.

THEOREM 71.

170. If any two chords, in a circle, be produced to meet each other, the rectangle of the two distances, from the point of intersection to each extremity of the one chord, is equal to the rectangle of the two distances from the point of intersection to each extremity of the other chord.



Let AB and CD be two chords, and let them be produced to meet in O; $OA \times OB = OD \times OC$.

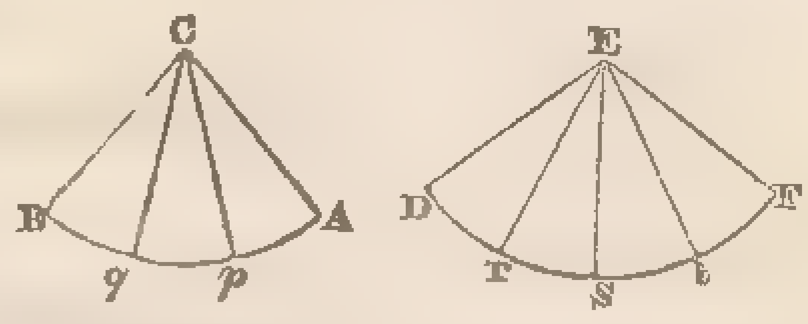
For, join AC and BD; then, in the triangles AOC and DOB the angle at O is common, and the angle $A = D$ (92); therefore the third angle, ACB, of the one triangle, is equal to the third angle DBO, of the other; consequently, the triangles AOC and DOB are similar, and their homologous sides proportional.

Whence $AO : OC :: DO : OB$

Wherefore, $AO \times OB = OD \times OC$.

### THEOREM 72.

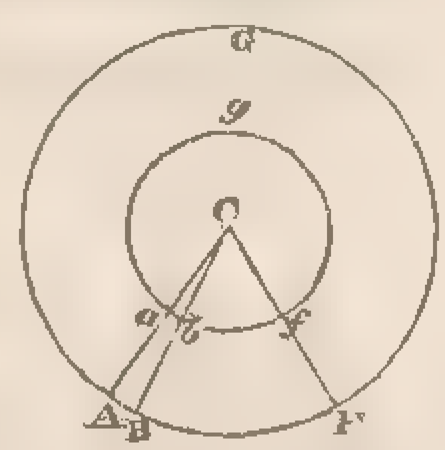
171. In the same circle, or in equal circles, any angles, ACB, DEF, at the centres, are to each other as the arcs AB, DF, of the circles intercepted between the lines which contain the angles.




Let us suppose that the arc AB contains three of such parts as DF contains four. Let A$p$, $pq$, $q$B, be the equal parts in AB, and D$r$, $rs$, &c. the equal parts in DF: draw the lines C$p$, C$q$, E$r$, E$s$, &c.; the angles AC$p$, $p$C$q$, $q$CB, DE$r$, &c. are all equal; therefore, as the arc AB contains $\frac{1}{4}$th part of the arc DF three times, the angle ACB will evidently contain $\frac{1}{4}$ of the angle DEF also three times; and, in general, whatever number of times the arc AB contains some part of the arc DF, the same number of times will the angle ACB contain a like part of the angle DEF.

### THEOREM 73.

172. In two different circles, similar arcs are as the radii of the circles.




Let the circles AFG, *afg*, be each described from the centre C. Draw the radii CA, CF, then the arcs A$f$ and $af$ are similar. Draw CB, indefinitely, near CA, and the sectors C$ab$, CAB, will approach very nearly to isosceles triangles, which are similar to each other; therefore, C$a$ : CA :: $ab$ : AB; let BF be divided into small arcs, each equal to AB, and draw the radii from each point of division; then $bf$ will contain as many arcs, each equal to $ab$, as the arc BF contains arcs equal to AB; therefore $af$ is the same multiple of $ab$ that AF is of AB; whence C$a$ : CA :: $af$ : AF.

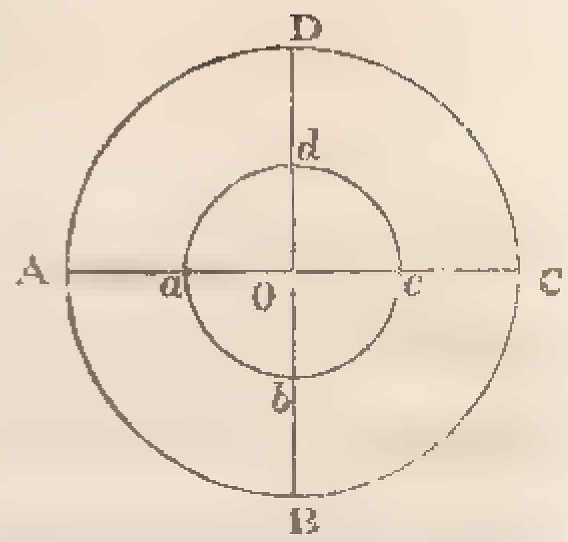
### THEOREM 74.

173. The circumference of circles are to one another as their diameters.

For, let the circumferences ABCD, *abcd*, be divided into quadrants by the radii O$a$A, O$b$B, O$c$C, O$d$D, then the quadrants AB, *ab*, will be similar arcs;

therefore, OA : O$a$ :: AB : $ab$

wherefore, OA : O$a$ :: 4AB : 4$ab$.




# PRACTICAL GEOMETRY.

### PROBLEM 1.

174. To make an angle at a given point, E, (*fig.* 35, *pl.* I,) in a straight line, DE, equal to a given angle ABC.

From the centre B, with any radius, describe an arc *gh*, cutting BA at *g*, and BC at *h*; from the point E, with the same radius, describe an arc, *ik*, cutting ED at *i*: make *ik* equal to *gh*, and through the point *k* draw EF; then the angle DEF will be equal to the given angle ABC.

### PROBLEM 2.

175. To bisect a given angle ABC (*fig.* 36, *pl.* I).

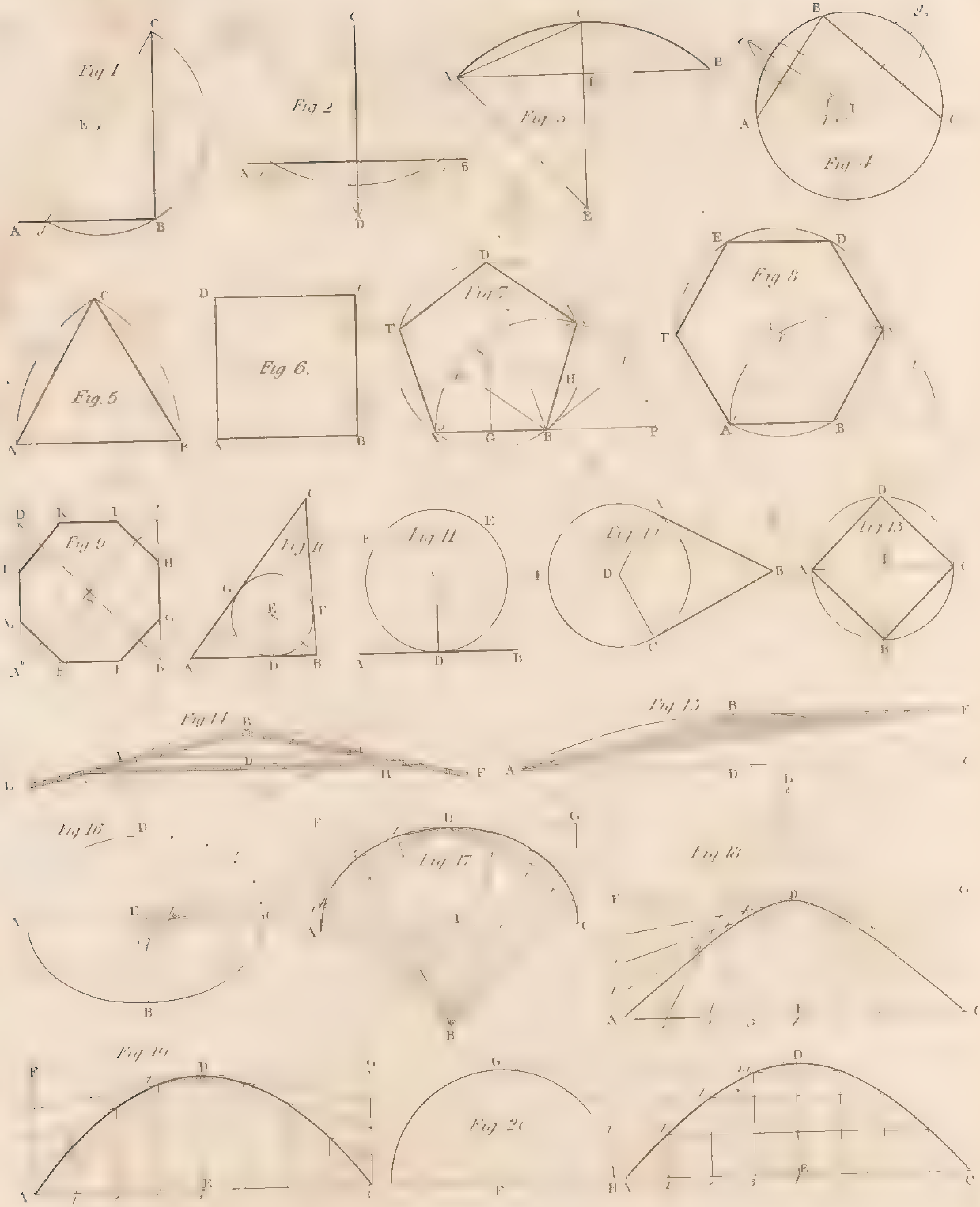
From BA and BC cut off B*e* and B*f*, equal to each other; from the points *e* and *f*, as centres, with any radius greater than the distance *ef*, describe arcs, cutting each other at G, and join BG, which will bisect the angle ABC, as required.

### PROBLEM 3.

176. Through a given point *g*, (*fig.* 37, *pl.* I,) to draw a straight line parallel to a given straight line, AB.

From *g* draw *ge*, to cut AB at any angle in the point *e*: in AB take any other point *f*; make the angle B*fh* equal to *feg*, and make *fh* equal to

# GEOMETRY.



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*eg*, and through the points *g* and *h* draw the line CD; then CD will pass through *g* parallel to AB, as required.

PROBLEM 4.

177. At a given distance, parallel to a given straight line, AB, (*fig*. 38, *pl.* I,) to draw a straight line, CD.

In the given straight line AB, take any two points, *e* and *f*; and, from the centres *e* and *f*, with the given distance, describe arcs at *p* and *q*; draw the line CD, to touch the arcs *p* and *q*; then CD will be parallel to AB, at the distance required.

PROBLEM 5.

178. To bisect a given straight line, CD, (*fig*. 39, *pl.* I,) by a perpendicular.

From the points C and D, with any distance greater than the half of CD, describe arcs cutting each other in A and B: join AB, and this line will bisect AB perpendicularly.

PROBLEM 6.

179. From a given point C, (*fig*. 40, *pl.* I,) in a given straight line, AB, to erect a perpendicular.

In the straight line, AB, take any two points, *e* and *f*, equally distant from C: from the points *e* and *f*, with any equal radius, greater than the half of *ef*, describe arcs cutting each other at D, and draw CD, which will be perpendicular to AB.

PROBLEM 7.

180. From a given point, B, (*fig*. 1, *pl.* II,) at the extremity of a given straight line, AB, to draw a perpendicular.

Take any point, E, above the line AB, and, with the radius BE, describe the arc *d*BC, cutting AB in *d*: draw the straight line *d*EC, and join BC, which will be the perpendicular required.

PROBLEM 8.

181. From a given point, C, (*fig*. 2, *pl.* II,) to let fall a perpendicular to a given straight line, AB.

From the point C, with any radius greater than the distance of AB, describe an arc cutting AB at *e* and *f*; from the points *e* and *f*, as centres, with any equal radius greater than the half of A, describe arcs cutting each other in D, and draw CD, which will be the perpendicular required.

PROBLEM 9.

182. To describe the segment of a circle, which shall have a given length or chord, AB, (*fig.* 3, *pl.* II,) and a given breadth, or *versed sine*, CD.*

By problem 2, bisect the straight line AB, by a perpendicular CE; from the point D, where the perpendicular cuts the chord AB, make DC equal to the breadth or versed sine; join AC; and, by problem 1, make the angle CAE equal to the angle ACE: from E, as a centre, with the radius EA or EC, describe the arc ACB, which will be the segment required.

PROBLEM 10.

183. Through three given points, A, B, C, (*fig.* 4, *pl.* II,) to describe the circumference of a circle.

Join AB, BC; and, by problem 2, bisect each of the lines AB and BC by a perpendicular, and let the perpendiculars meet each other in I: from the centre I, with the distance IA, IB, or IC, describe the circle ABC, which is that required.

PROBLEM 11.

184. Upon a given straight line, AB, (*fig.* 5, *pl.* II,) to describe an equilateral triangle.

From the centres A and B, with the radius AB, describe arcs cutting each other at C. Join AC and BC; then ABC will be the equilateral triangle required.

PROBLEM 12.

185. Upon a given straight line, AB, (*fig.* 6, *pl.* II,) to describe a square.

From the point B, by problem 5, draw BC perpendicular to AB; make BC equal to AB: from the points A and C, as centres, with a radius equal to AB

* The meaning of *sine*, *versed sine*, &c. is given in Trigonometry, hereafter.

or B, describe arcs cutting each other in D, and join AD, and DC; then ABCD is the square required.

PROBLEM 13.

186. Upon a given straight line, AB, (*figures* 7 and 8, *pl.* II,) to describe a regular polygon of any number of sides.

Produce the side AB to P, and on AP, from the centre B, describe a semicircle ACP; divide the semi-circumference ACP into as many equal parts as the number of sides intended; through the second division, from P, draw the line BC; bisect AB and BC by perpendiculars cutting each other in S; from S, with the radius AS, BS, or CS, describe a circle ABCDE, then carry the side AB or BC round the remaining part of the arc, which will be found to contain the remaining sides of the number required.

*Figure* 7 is an example of a pentagon. *Figure* 8 is an example of a hexagon: but, in this figure, we need not proceed by the general method; we have only to make a radius of the given side AB; and take the points A and B as centres; and form the arcs AG and BG, and strike a circle with the radius GA or GB, which will contain the side AB six times.

PROBLEM 14.

187. In a given square, ABCD, (*fig.* 9, *pl.* II,) to inscribe a regular octagon, so that four alternate sides of the octagon may coincide with four sides of the square.

Draw the diagonals AC and BD, cutting each other in S; on the sides of the square make AL, AF, BE, BH; CG, CK; and DI, DM, each equal to half the diagonal; join ME, FG, HI, KL; then will FGHIKLMEF be the octagon required.

PROBLEM 15.

188. In a given triangle ABC, (*fig.* 10, *pl.* II,) to inscribe a circle.

Bisect any two angles, A and B, by the straight lines AE and BE, and the point E, the intersection of these two lines will be the centre of the inscribed circle: draw ED perpendicular to AB, cutting AB in D; from E, with the radius ED, describe the circle DFG, which will be inscribed in the triangle ABC, as required.

### PROBLEM 16.

189. A circle, DEF, (*fig.* 11, *pl.* II,) and a line AB, touching it, being given, to find the point of contact.

From the centre C draw the perpendicular CD, cutting AB in D, which is the point of contact required.

### PROBLEM 17.

190. Two straight lines, AB, BC, (*fig.* 12, *pl.* II,) forming any angle, being given, to describe a circle to touch each of these lines at a given point, A, in one of them.

Make BC equal to BA, and draw AD perpendicular to AB, and CD perpendicular to BC; from the point of intersection D, with the radius DA or DC, describe the circle ACE, which is that required.

### PROBLEM 18.

191. In a given circle, ABCD, (*fig.* 13, *pl.* II,) to inscribe a square.

Draw the diameters AC and BD at right angles, and join AB, BC, CD, DA; then ABCD will be the square required.

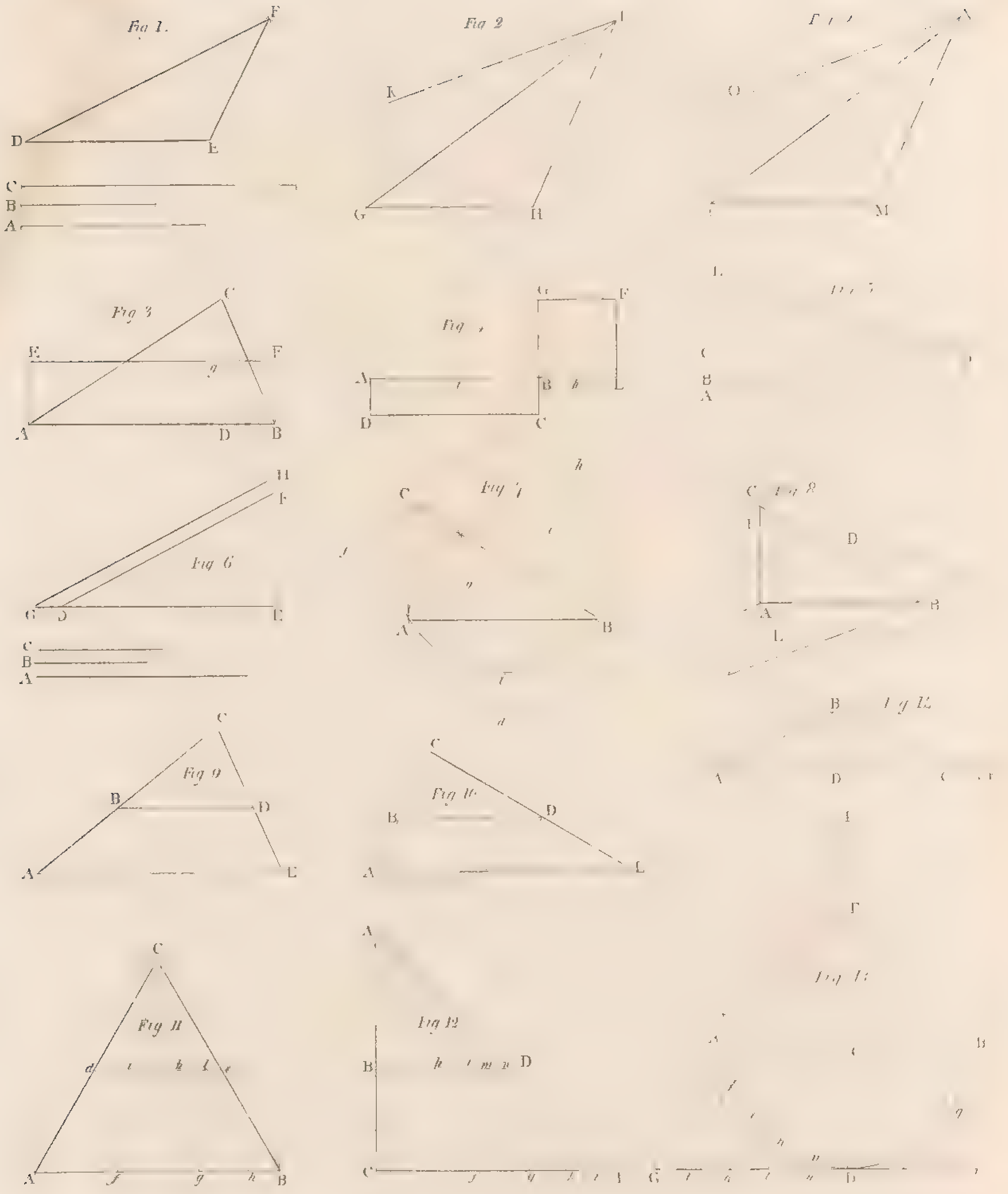
### PROBLEM 19.

192. To describe a segment, ABC, of a circle, by means of an angle.

Let AC (*fig.* 14, *pl.* II,) be the length or chord, and DB the versed sine. Join BA and BC; produce BA to E, and BC to F, making BE and BF of any length, not less than the chord AC. Prepare two straight edges, BE and BF, and fasten them together at the angle B, so that their outer edges may form the angle ABC; and, to keep them to the extent, fix another slip, GH, to each straight edge at G and H. Bring the angular point B to A, then move the angle thus formed by the straight edges, so that the edge BE may always move upon the point A, and the edge BF upon the point C; then if, during the time of moving, a pencil be held to the angular point B, and the point to trace over the plane, the segment of a circle will be described. Or thus—

193. Let AC (*fig.* 15, *pl.* II,) be the length or chord, and BD the versed sine. Join AB, and draw BE parallel to AC, making BE of any length, not

# GEOMETRY.

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less than AB. Form a triangular piece of wood, ABE; bring the angular point B, of the triangle, to the point A; and move the triangle, so that the side BA may slide upon A, and the side BE upon B: then if, during the motion, a pencil be held at the angular point B, with its point tracing over the plane, the arc AB will be described by the point of the pencil. The arc AB being described, the arc BC will be described in a similar manner; and, consequently, the whole segment of the circle, as required to be done.

### PROBLEM 20.

To describe an ellipse to any length and breadth.

194. *Method the first* (*fig*. 16, *pl*. II).—Draw the line AC, and make AC equal to the length required; bisect AC by a perpendicular BD, and make EB and ED each equal to half the breadth.

To find any point, *g*, in the curve; with the difference of ED and EA, as a radius, from any point *f*, in EB, describe an arc, cutting EC in *h*. Draw *f h*, and produce it to *g*, and make *hg* equal to EB or ED; then *g* will be a point in the curve, as required. Or thus—

195. Divide AE and AF (*fig*. 17, *pl*. II,) each into the same number of equal parts, as here into five. Through the points of section 1, 2, 3, &c. draw the lines B*h*, B*i*, B*k*, &c.; and through the points of section, 1, 2, 3, &c., in AF, draw the lines 1D, 2D, 3D, &c., cutting the former lines drawn from B, in the points, *h*, *i*, *k*, &c.; then through the points A, *h*, *i*, *k*, &c. draw a curve, and we shall have the fourth part, or quarter, of the whole curve. In the same manner the other quarter DC may be found.

And, by taking the point D, instead of B, and by describing the rectangle upon AC, so that the opposite side may pass through B, and dividing and drawing lines in the same manner, we shall have the whole curve.

### PROBLEM 21.

196. Having given three straight lines, any two of which, taken together, being greater than the remaining one, to construct a triangle.

Let A, B, and C, (*fig*. 1, *pl*. III,) be the three lines given. Make DE equal to A; and from D, as a centre, with a distance equal to C, describe an arc;

and from E, as a centre, with a distance equal to B, describe another arc, meeting the former in F; join DF and EF; and DEF will be the triangle required.

PROBLEM 22.

197. Given a trapezium, to construct another every way equal to it.

Let GHIK (*fig.* 2, *pl.* III,) be the given trapezium. Draw GI, the diagonal, and make LN equal thereto; on LN describe the triangle LNM, equal to the triangle GHI, by the last problem. Describe, also, the triangle LON, equal to the triangle GKI, and the thing is done.

PROBLEM 23.

198. Given a triangle, to make a rectangle equal to it.

Let ABC (*fig.* 3, *pl.* III,) be a triangle. From C draw CD perpendicular to AB, which bisect in *g*, by the straight line EF, drawn parallel to AB; from the points A and B draw the perpendiculars AE and BF; and the rectangle ABFE is equal to the triangle ABC.

PROBLEM 24.

199. To make a square equal to a given rectangle.

Let ABCD (*fig.* 4, *pl.* III,) be a rectangle; produce the side AB till B*h* be equal to BC; on A*h* describe a semi-circle, and produce BC to meet the arc G; on BG describe the square BGFE, and the thing is done.

PROBLEM 25.

200. To find the side of a square equal to two squares whose sides are given.

Let A and B (*fig.* 5, *pl.* III,) be the given sides. Make CD equal to A, and at C, draw CE perpendicular to CD, and make it equal to B; join ED, and ED will be the side of a square equal to both the given squares.

PROBLEM 26.

201. Given the sides of three squares, to find the side of another equal to the three.

Let A, B, and C, (*fig.* 6, *pl.* III,) be the given sides. Find DF, as in the last problem, equal to both the squares, whose sides are A and B; produce ED till EG equal DF, and make EH equal to C; join GH, and the thing is done.

PROBLEM 27.

202. Given two circles, to find a third equal to them both.

Let AB and AC, (*fig.* 7, *pl.* III,) be the diameters of the given circles, perpendicular to each other at the point A; join CB, on which describe a circle, and the thing is done.

PROBLEM 28.

203. Given any two similar figures, to find another equal and similar to them both.

Let E and F, (*fig.* 8, *pl.* III,) have their sides AB and AC placed perpendicular to each other; join BC, on which describe a figure similar to E or F, and the thing is done.

PROBLEM 29.

204. Given three straight lines, to find a fourth, proportional.

Let AC, (*fig.* 9, *pl.* III,) one of the given lines, make any angle with the line CE, and from B, one extremity of another given line, draw BD, the third, any how to meet CE, and through A draw AE parallel to BD, and AE will be the fourth proportional.

PROBLEM 30.

205. Having given two lines, to find a third, proportional.

Let CB and CD (*fig.* 10, *pl.* III,) be the given lines, and let them have any inclination at the point C; join BD, and produce CD and CB to A and E, making CA equal to CD; through A draw AE parallel to BD, and CE will be the third proportional required.

PROBLEM 31.

206. To divide a given line in the same proportion as another line is divided.

Let *de* (*fig.* 11, *pl.* III,) be the line proposed for division. On *de* describe an equilateral triangle, *d*C*e*; produce the sides C*d* and C*e* till each of them be equal to AB; join AB, and from C to the points of division, *f*, *g*, *h*, draw the lines C*f*, C*g*, and C*h*, which will cut *de* in the points *i*, *h*, *l*, in the same proportion as AB is cut. Or thus—

207. Let BD be the given line (*fig.* 12, *pl.* III,) whose division is required. Upon BD raise BA perpendicular at the point B, which make equal to BD; produce AB till AC be equal to the given divided line CE; draw CE perpendicular to AC, and produce AD to E, to the points of division *f*, *g*, *h*, *i*; from A draw the lines A*f*, A*g*, A*h*, and A*i*, which will divide the line BD in the given proportion.

PROBLEM 32.

208. To divide the quadrant of a circle into any number of equal parts.

Bisect the diameter AB (*fig.* 13, *pl.* III,) perpendicularly in C, produce CE till EF be equal to three-fourths of AC or BC. Join FA, which produce to meet DG, drawn through D, parallel to AB; divide DG into the proposed number of equal parts in the points *h*, *i*, *k*, *l*, and join F*h*, F*i*, F*k*, and F*l*, which will divide the quadrant AD, into the proposed number of equal parts nearly.

PROBLEM 33.

209. To find a line equal to a given arc of a circle.

Let ABC (*fig.* 14, *pl.* III,) be the given arc. Join AC, which bisect in D, by the perpendicular BD; join AB, and produce AC till AE be equal twice AB; divide CE into three equal parts, and make EF equal to one of these parts; then will AF be nearly equal to the arc ABC.

PROBLEM A.

210. Having the abscissa ED, (*figures* 1 and 2, *pl.* IV,) and a double ordinate AB, to describe a parabola.

Produce ED to B, making DB equal to DE, and join AB and CB. Divide AB into any number of equal parts, numbering them from A to B, and divide BC into the same number of equal parts, numbering them from B to C. Join 1,1; 2,2; 3,3; &c., and the parts of the straight lines, comprehended between the intersections, will form the parabola, being all tangents at different points.

PROBLEM B.

204[A]. To describe a parabola by a continued motion.

Let GH (*fig.* 3, *pl.* IV,) be the straight edge of a ruler, and KLQ the internal right angle of a square, and let the edge which is parallel to KL coincide


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with the straight edge GH. Suppose now one end of a string fastened at F, and the other end to the end G of the square. Let FI be perpendicular to GH, meeting GH in I. Suppose the ruler to remain fixed, and the square to be moved, keeping the upper edge against the straight edge GH; then, if both parts, FM, MQ, be kept straight by a pencil at M, the point M will describe the half of the parabolic curve.

### PROBLEM C.

$205^{B}$. Given the axis major and two foci of a conic section, to describe the curve.

Let AB (*figures* 5 and 6, *pl.* IV,) be the axis major, and the points F, *f*, the foci. Produce BA, if necessary, to F, and make AI equal to AF; from the remote focus, *f*, describe an arc QI. Through Q draw *f* M; then find the point M, by sloping with a compass or dividers, so that FM may be equal to MQ; then M is a point in the curve.

By employing F in the same manner as has now been done, in respect of *f*, we shall obtain the curve *r* B *s*.

N.B. In the ellipse, *fig*. 6, it will be most convenient to describe one-half by means of the focus *f*, and then the other by the other focus F.

In the parabola, *fig*. 4 , the arc QI will become a straight line. This being understood, the point M, and every other point will be found, as in *figs*. 5 and 6*.

### PROBLEM D.

$206^{C}$. To describe an ellipse having the two axes given.

On AB (*fig*. 7, *pl*. IV,) describe the rectangle GHIK, whose sides GH and GK are equal to the given axes. Divide CD into any number of parts, *q*, *r*, *s*, *t*, and DG into the same number, *a*, *b*, *c*, *d*; from B, through the points of division *q*, *r*, *s*, *t*, draw lines BM, &c.; and from A, to the points of division, *a*, *b*, *c*, *d*, draw A*a*, A*b*, &c., meeting the former in M; then will M be a point in the curve: and thus may all the points be found, through which draw the curve itself, and what was required is done. Or thus—

* This ingenious method of describing the conic section is due to the talents of Mr. Robert Gibson, of Hampstead.

207[D]. Let F and $f$ be the foci, (*fig.* 8, *pl.* IV.) Make FM + $f$M equal to AB, supposing FM + $f$M to be a cord or string. Then move the point M round, taking care to keep the string always tight, and the point M will, in its motion, trace out the curve ADBD, which is the ellipse required. Or thus—

208[E]. In *fig.* 9, *pl.* IV, $g\,i$ is the semi-transverse, and $g\,h$ the difference of the semi-axes. The point $g$ is supposed to move in the groove exhibited in one arm of the trammel, while $h$ moves in the other, and the point $i$ traces out the curve.

PROBLEM E.

209[F]. To describe an ellipse round a given rectangle.

In *fig.* 10, *pl.* IV, let IT be half the longest side of the rectangle, and make IG equal to IT; join TG, cutting AB in H; Then GI is the semi-transverse, and GH the difference of the semi-axes; therefore, the curve may be described, as in the last problem.

PROBLEM F.

210[G]. To describe an ellipse by means of circles.

From the centre C, (*fig.* 11, *pl.* IV,) with a distance equal to the semi-conjugate, describe the quadrant D$hg$; and, from the same centre, with the semi-transverse as a distance, describe the arc $i$B. Bisect D$hg$ in $h$; join C$h$, which produce to $i$; through $h$ draw $hk$ parallel to CB, and from $i$, draw $ik$ perpendicular to $hk$: then will $k$ be a point in the curve. Produce DC to $l$, and bisect the distance D$k$ perpendicularly, which bisecting line produce to meet DC in $l$, then will $l$ be the centre of the circle, describing one part of the curve. Again, through $l$ draw $lm$ parallel to $hk$ meeting the arc D$nm$ in $m$; join $m$B, which produce to meet the curve in $n$; join $nl$, cutting AB in $g$; $g$ is the centre of the circle whence the vertical part of the curve is described.

PROBLEM 34.

211. To describe an *hyperbola,* or a figure that may have any curvature at the summit that we please (*fig.* 18. *pl.* II).

Let AC be the base, or what is called a *double ordinate:* make ED equal to the height, in the middle of AC; then upon AC, as a side, describe a rectangle,

AFGC, so that the opposite side may pass through D; produce ED to the point B; take the point B, farther or nearer from D, according as the curvature at D is required to be flatter or quicker; and observe that, the quicker the curve is at D the flatter it will be towards A and C. The point B being thus fixed, divide AE into any number of parts, as here into four; also, divide AF into the same number of parts, viz. four; through 1, 2, 3, &c., the points of section in AE, draw lines to B; and through the points of section, 1, 2, 3, &c. in AF, draw lines to D, cutting the former lines drawn to B, in the points *h, i, k,* &c.; and, through the points A, *h, i, k,* &c., draw a curve, which will be the half of an hyperbola, or an hyperbolic curve.

### PROBLEM 35.

212. To describe a *parabola* upon a given ordinate, AE, and a given abscissa, ED* (*fig.* 19, *pl.* II).

Make EC equal to EA, and complete the rectangle AFGC; so that the opposite side may pass through D. Proceed as in the two former problems, 33 and 34; excepting that, instead of drawing the lines to B, through the points 1, 2, 3, &c., in AE, to draw them parallel to ED.

### PROBLEM 36.

213. To describe the figure of the Sines† (*fig.* 20, *pl.* II).

Describe the quadrant FHG, equal to the height of the figure, and divide the arc HG into any number of equal parts; the more of these the more perfect the operation will be; and extend the chords to double the number of parts upon the line AC, which is a continuation of FH, and mark the points of division. Draw the lines 1*k*, 2*l*, 3*m*, &c. perpendicular to AC; and, from the points 1, 2, 3, &c. of division in the quadrant, draw lines 1*k*, 2*l*, 3*m*, &c. parallel to AC, and through the points A, *k, l, m,* &c., draw a curve, which will be the figure of the sines, as required.

* The PARABOLA is a figure arising from the section of a cone, when cut by a plane parallel to one of its sides. This, with other terms in Conics, is fully described, under CONIC SECTIONS, hereafter.

† The SINE, or *right sine*, of an arch, is a right line drawn from one end of that arch, perpendicular to a radius, drawn to the other end of the same.—See TRIGONOMETRY, hereafter.

# GEOMETRY OF SOLIDS.

## DEFINITIONS OF SOLIDS.

214. A Right Cylinder is that which is formed by the revolution of a rectangle about one of its sides: the line round which the rectangle revolves is called the *axis* (plural *axes);* and the circles generated by the two opposite sides of the rectangle, perpendicular to the axes, are termed the ends or bases. The surface of the cylinder, generated by the line parallel to the axis, is termed the *curved surface,* which is either straight or convex, according as a straight edge is applied, parallel to the axis, or in any other direction.

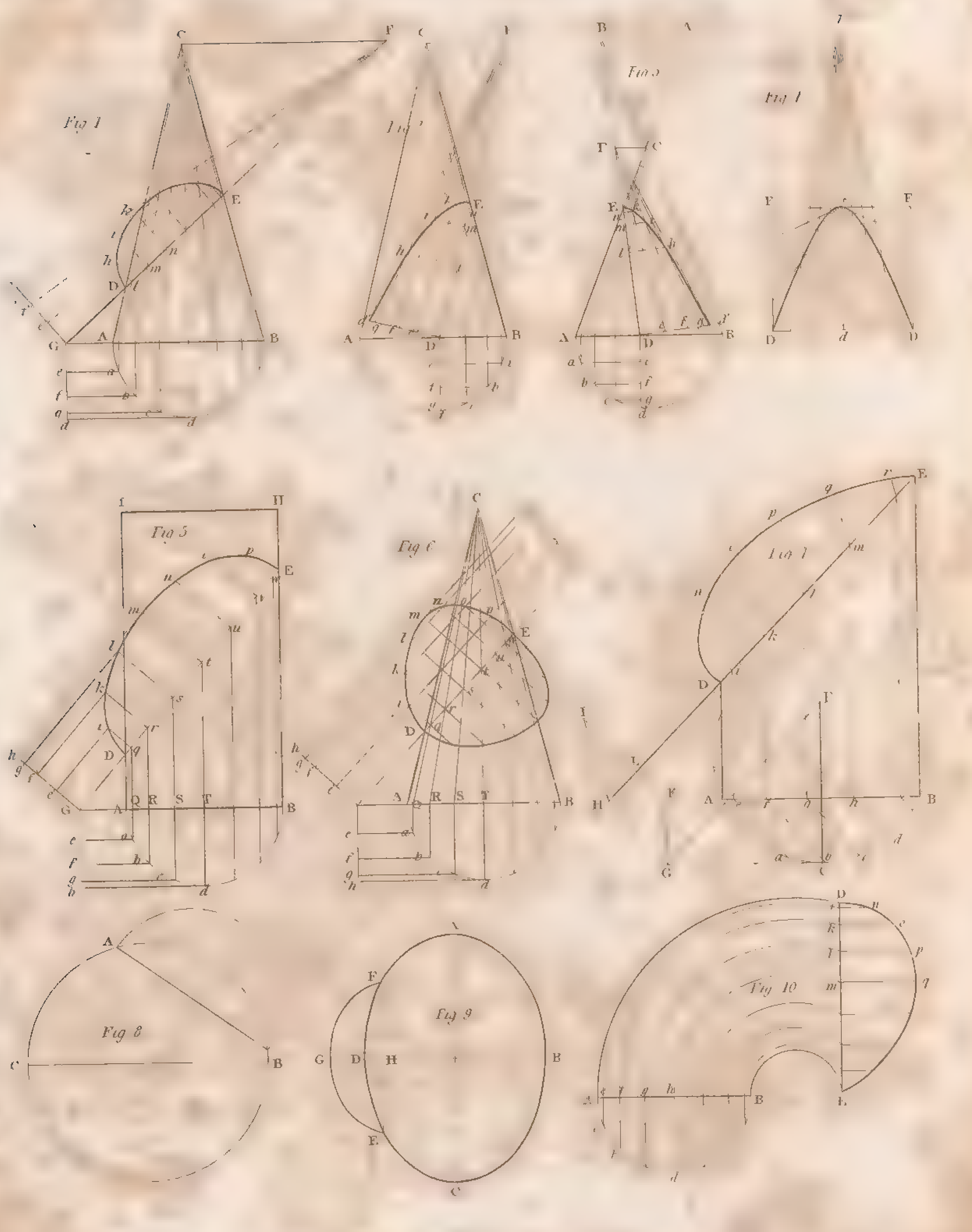
215. A Right Cone is that which is formed by supposing a right-angled triangle to revolve about one of its legs or perpendicular sides; the fixed leg, or line, is called the *axis;* the surface generated by the other leg is called the *base;* and the surface formed by the hypothenuse, or side opposite the right angle, is denominated the *curved surface,* which is either straight or convex, according as a straight edge is applied upon the surface from the vertex, or in any other direction.

216. A Sphere or Globe is that which is formed by supposing a semi-circle to revolve upon its diameter; the diameter upon which the semi-circle revolves is called the *axis,* and the surface formed by the arc of the semi-circle is called the *curved surface,* which is convex, in whatever way it may be tried by a straight edge.

217. An Ellipsoid is formed or generated by supposing a semi-ellipse to revolve upon one of its axes; the axis thus fixed is called the *axis of the ellipsoid,* and the surface generated by the curve is termed the *curved surface.*

# GEOMETRY.

## SECTIONS OF SOLIDS.



Drawn by P. Nicholson

London, Published by Thos Kelly, 17 Pat

### PROBLEM 37.

218. To describe a conic section, from the cone, through a line given in position, in the section passing through the axis.

Let ABC, (*figures* 1, 2, 3, *pl.* VI,) be the section of a right cone, and let DE be the line of section. Through the apex or top of the cone, C, draw CF, parallel to the base AB of the section, and produce ED to meet AB in D, as in *figures* 2 and 3, or AB produced in G, as in *fig.* 1, as also to meet CF in F. On AB describe a semi-circle, which will be equal to half the base of the cone. In the semi-circle take any number of points, *a*, *b*, *c*, &c. Draw D*d*, in *figures* 2 and 3, and G*d* in *fig.* 1, perpendicular to AB and G*d'*, in *fig.* 1, perpendicular to GF; as, also, D*d'*, *figures* 2 and 3, perpendicular to DF. From the points *a*, *b*, *c*, &c. draw lines, *ae*, *bf*, *cg*, &c., cutting G*d* (*figure* 1) and D*d* (*figures* 2 and 3) in the points *e*, *f*, *g*, &c. In *figure* 1, make G*e'*, G*f'*, G*g'*, &c. equal to G*e*, G*f*, G*g*, &c.; and in D*d'*, (*figures* 2 and 3,) make D*e'*, D*f'*, D*g'*, &c. equal to D*e*, D*f*, D*g*, &c. Through the points *e'*, *f'*, *g'*, &c. draw lines to F. Through the points *a*, *b*, *c*, &c. draw lines perpendicular to AB. From the points of section, in AB, draw lines to the vertex C of the cone, cutting the sectional line, DE, in *l*, *m*, *n*, &c. Through the points of section *l*, *m*, *n*, &c., draw *lh*, *mi*, *nk*, &c. perpendicular to DE. Through the points D, *h*, *i*, *k*, &c. in *fig.* 1, or *d'*, *h*, *i*, *k*, &c. *figures* 2 and 3, draw a curve, which will be the conic section required.

### OBSERVATIONS.

219. In the first of these figures, the line of section cuts both sides of the section of the cone; in this case, the curve D*hik* and *e*E is an *Ellipse*. In *fig.* 2, the line of section DE is parallel to the side AC of the section of the cone; in this case, the curve *d'hi*, &c. E, is a *Parabola*. In *fig.* 3, the line of section, DE, is not parallel to any side of the cone; it must, therefore, when produced with the sides of the section through the axis, meet each of these two sides in different points: in this case, the section *d'*, *h*, *i*, &c., E, is either an *Ellipse* or

*Hyperbola;* but the case is determined to be an hyperbola by the line of section meeting the opposite side BC at AC, where it cuts above the vertex at the point B′.

Here we may observe that the line of section, DE, is the same as that which has before been called the *abscissa,* the part EB produced, contained between the two sides of the section, is called the *axis major;* and the line D*d*, perpendicular to DE, an *ordinate.*

Hence the same section may be found by the method already shown in the problem; viz. by drawing any straight line, *deb, fig.* 4: make *de* equal to DE, *fig.* 3, and *eb* equal to EB, *fig.* 3. Through *d* draw the straight line DD at right angles to *db′*: make *d*D equal to D*d′*, *fig.* 3; then, with the axis major *b′e*, the abscissa *ed*, and the ordinate *d*D, on each side of the abscissa describe the curve of the hyperbola, which will be of the same species as that shown in *fig.* 3.

PROBLEM 38.

220. To describe a cylindric section, through a line given in position, upon the section passing through its axis (*fig.* 4, *pl.* VI).

This is no more than a particular case of the last problem. For a cylinder may be considered as a cone, having its apex at an infinite distance from its base; or, practically, at a vast distance from its base. In this case all the lines, for a short distance, would differ insensibly from parallel lines; and this is the construction shown at *fig.* 5, which is therefore evident. But as the section of a cylinder so frequently occurs, I shall here give a more practical description of it. Thus—

Let ABHI be a section of a right cylinder, passing through its axis, AB being the side which passes through the base, and let DE be the line of section. On AB describe a semi-circle; and, in the arc, take any number of points, *a*, *b*, *c*, &c. from which draw lines perpendicular to the diameter, AB, cutting it in Q, R, S, &c.: perpendicular to AB, or parallel to AI or BH, draw the lines Q*q*, R*r*, S*s*, &c. cutting the line of section, DE, in the points, *q*, *r*, *s*, &c.: from the points of section, *q*, *r*, *s*, &c. draw the lines *qi*, *rk*, *sl*, &c. per-

pendicular to the line of section, DE. Make the ordinates *qi, rk, sl,* &c. each respectively equal to the ordinates Q*a*, R*b*, S*c*, &c.; and through the points D, *i*, *k*, *l*, &c. to E, draw a curve, which will evidently be the section of the cylinder, as required.

*The same may be done in this manner,* viz.—Bisect the line of section DE in the point *t*. Draw *tm* perpendicular to DE. Make *tm* equal to the radius of the circle which forms the end of the cylinder; then, with the *axis major,* DE, and the semi-axis minor, *tm,* describe a semi-ellipse, which will be the section of the cylinder required.

### A DEFINITION.

221. A Cuneoid is a solid ending in a straight line, in which, if any point be taken, a perpendicular from that point may be made to coincide with the surface: the end of the cuneoid may be of any form whatever.

The cuneoid, which occurs in architecture, has a semi-circular or a semi-elliptical end, parallel to the straight line to which the perpendicular is applied.

### PROBLEM 39.

222. To find the section of a cuneoid, with a semi-circular base, the given *data* being a section through the axis, perpendicular to the vertex, or sharp end, and the line of section upon that end.

Let ABC, (*fig.* 6, *pl.* VI,) be the section through the axis, perpendicular to the sharp edge, and let DE be the line of section.

This construction is similar to that of finding the section of a cylinder, excepting that, instead of drawing parallel lines from the base, AB, they are, in this figure, drawn from the points of section in AB to the point C, which is the vertex of the cuneoid: the ordinates, Q*a*, R*b*, S*c*, &c., being transferred, respectively, to *qi*, *rk*, *sl*, &c.; and the curve D, *i*, *k*, *l*, &c. to E, being drawn through the points, D, *i*, *k*, *l*, &c., by hand.

### PROBLEM 40.

223. Given the position of the seats of three points, in the circumference of the base of a cylinder, and the lengths of the perpendiculars intercepted

between the points and their seats, to find the section of the cylinder passing through these three points.

Through the three points, A, B, C, (*fig.* 7, *pl.* VI,) describe the circumference of a circle. Join the two remote points, A and B, and draw AD, CF, and BE, perpendicular to AB. Make AD equal to the height upon A, BE equal to the height upon B, and CF equal to the height upon C. Produce BA and ED to meet each other in H: draw CG parallel to BH, and FG parallel to EH. Join GH. In GH take any point, G, and draw GK perpendicular to CG, cutting BH in K: from the point K draw KI, perpendicular to EH, cutting EH in L. From H, with the radius HG, describe an arc, cutting KI at I. Join HI. In the circumference, ACB, take any number of points *a, b, c,* &c., at pleasure, and draw *ae, bf, cg,* &c., parallel to GH, cutting AB at *e, f, g,* &c. Through the points *e, f, g,* &c., draw lines *ei, fk, gl,* &c., parallel to GK, or AD, or BE, cutting DE at *i, k, l,* &c.; from the points of section, *i, k, l,* &c., draw the lines *in, ko, lp,* &c., parallel to HI. Transfer the ordinates, *ea, fb, gc,* &c., to *in, ko, lp,* &c.; then, through the points D, *n, o, p,* &c. draw the curve D*nop*, &c. to E, and it will be the section cut by the plane, as required.

PROBLEM 41.

224. Given the great circle of a sphere, and the line of position of a section at right angles to that great circle, to find the form of the section.

Let ABC, (*fig.* 8, *pl.* VI,) be the great circle, and AB the line of section.

On AB, as a diameter, describe a semi-circle, which will be the section required: since all the sections of a sphere, or globe, are circles.

PROBLEM 42.

225. Given the section of an ellipsoid, passing through the fixed axis, and the line of position of another section, at right angles to the first section, to find the form of the section through that line.

Let ABCD, (*fig.* 9, *pl.* VI,) be the section through the fixed axis, and EF the line of position. Through the centre of the ellipsoid draw AC parallel to EF. Bisect EF in H, and draw HG perpendicular to EF. Find HG a fourth

proportional to AC, DB, HE. Then, with the axis major, EF, and the semi-axis minor, HG, describe a semi-ellipse, and it will be the section of the ellipsoid required.

If AC be the axis major, BD will be the axis minor. In this case, join DC, and draw EG parallel to DC; then HG will be the height found geometrically.

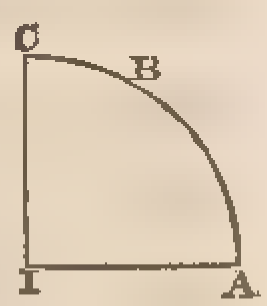
PROBLEM 43.

226. To find the section of a cylindric ring, perpendicular to the plane passing through the axis of the ring, the line of section being given.

Let ABED, (*fig.* 10, *pl.* VI,) be the section of the ring, passing through its axis, and let AB be a straight line, passing or tending to the centre of the two concentric circles, AD and BE; also, let DE be the line of section. On AB describe a semi-circle, and take *a, b, c,* &c., any number of points in its circumference; draw the ordinates, *ae, bf, cg,* &c. Through the points, *e, f, g,* &c., in the diameter AB, draw the concentric circles, *ei, fk, gl,* &c., cutting the sectional line DE in the points *i, k, l,* &c. Through the points, *i, k, l,* &c., draw *in, ko, lp,* &c., perpendicular to DE; transfer the ordinates *ea, fb, gc,* &c., of the semi-circle, to *in, ko, lp,* &c.: and, through the points D, *n, o, p,* &c. draw the curve, D*nopq*E, which is the section required.

# PLANE TRIGONOMETRY.

## DEFINITIONS OF TERMS IN TRIGONOMETRY.*

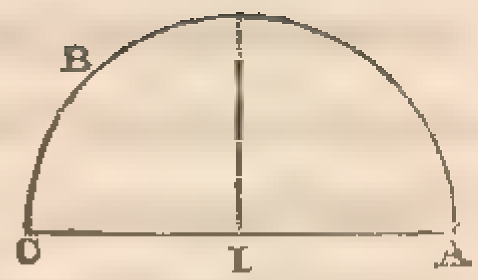



227. The Complement of an Arc is the difference between that arc and a quadrant or quarter of a circle.

Thus, the arc BC, which is the difference between AC and AB, is the complement of AB; and AB is, in like manner, the complement of BC.

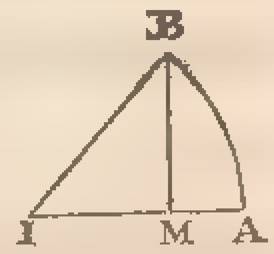
* Trigonometry is that branch of Geometry which treats exclusively on the properties, relations, and measurement, of triangles.

228. The Supplement of an Arc is the remainder between that arc and a semi-circle.

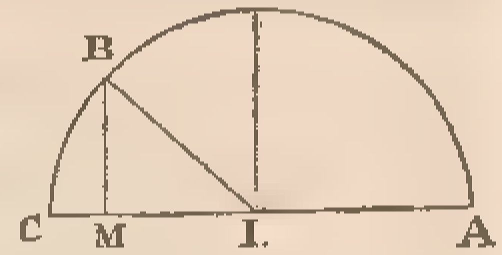



Thus, the arc given being AB, its supplement is BC.

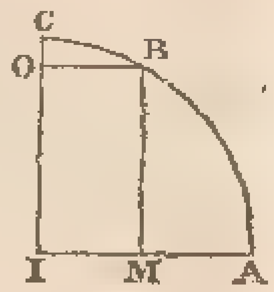
229. The Sine of an Arc is a straight line, drawn from one extremity of the arc, upon and perpendicular to a radius or diameter.



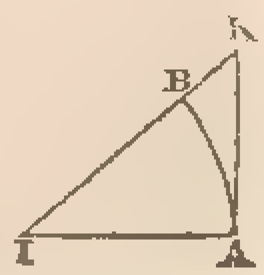

Thus, BM is the *sine* of the arc AB; and here it is evident that an arc and its supplement have the same sine.




230. The Co-sine of an Arc is the sine of the complement of that arc. Hence, BO or IM is the co-sine of the arc AB; and, therefore, the sine of the complement BC.

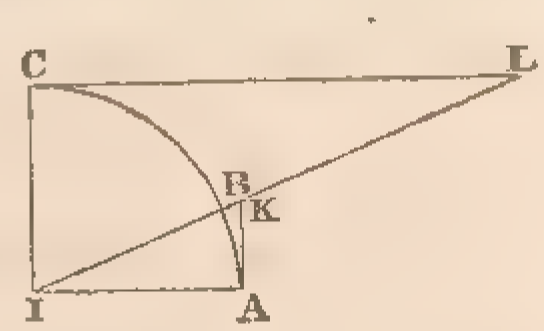



231. The Tangent of an Arc is a straight line, drawn from one extremity of the arc, where it touches it, to meet the prolongation of the radius through the other extremity.



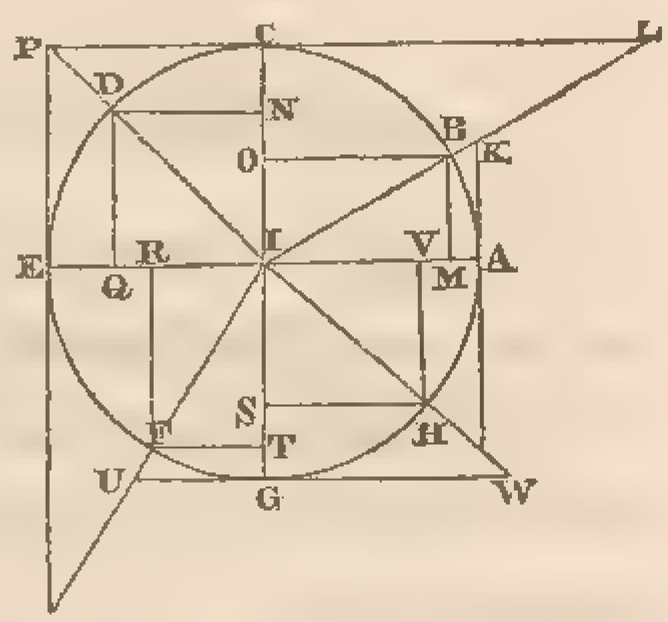

The line AK, touching the arc at A, and extended to meet the radius IB produced, is the tangent of the arc AB.

232. The Co-tangent of an Arc is the tangent of the complement of that arc.




Thus, CL is the co-tangent of the arc AB, or the tangent of the arc BC.

In the annexed diagram let AB, AC, AD, AE, AF, AG, AH, to A, be the several portions of the circumference, by supposing the point B to revolve round the circumference from A to B, C, D, E, F, G, H, the sine of any arc, in the first quadrant, increases from A to C, where it is the greatest possible, and then decreases to E, where it becomes zero; the sine will, therefore, be positive for the first semi-circumference, and in the other half it will be negative.

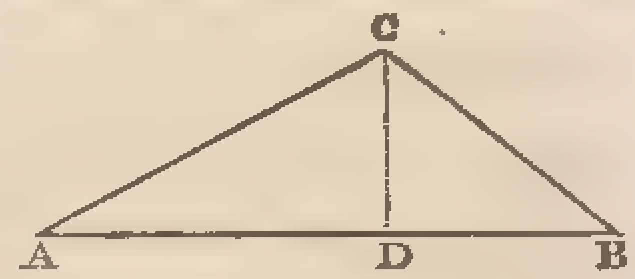


The *co-sine* will be positive in the first quarter, negative in the second and third, and again positive in the fourth.

The *tangent* will be positive in the first quarter, negative in the second, positive in the third, and negative in the fourth.

### TRIGONOMETRY.—THEOREM 1.

233. If a perpendicular be drawn from an angle of a triangle, to the opposite side, which is the base; then, as the base is to the sum of the two sides, so is the difference of the sides to the difference of the segments of the base.




For, (*theorem* 62, *page* 56) .... $AC^2-CD^2=AD^2$

and, again, (*theorem* 62) ....... $BC^2-CD^2=BD^2$.

Subtract the second equation from the first, and the result is .................... $AC^2-BC^2=AD^2-BD^2$:

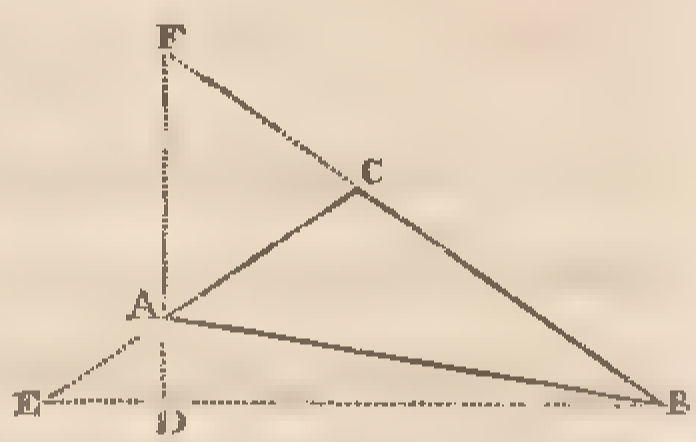
but, since the difference of the squares of any two quantities is equal to a rectangle contained by their sum and difference;

therefore.................... $(AC+BC)(AC-BC)=(AD+BD)(AD-BD)$

Whence, (*theorem* 40, *page* 41) $AD+BD : AC+BC :: AC-BC : AD-BD$.

### TRIGONOMETRY.—THEOREM 2.

234. The sum of the two sides of a triangle is to their difference as the tangent of half the sum of the angles at the base is to the tangent of half their difference.




Let ABC be a triangle; then, of the two sides, CA and CB, let CB be the greater. Produce CA to E, and make $CE=CB$, and join BE. Produce BC to F; and, through A, draw FD, perpendicular to EB, meeting it in D; then FBD will be half the sum of the angles at the base, and ABD half their difference. Likewise, DF is the tangent of the angle FBD, and AD the tangent of the angle ABD: moreover BF is the sum of the two sides BC, CA, and AE is their difference.

Then, by similar triangles, BFD, EAD,....$BF\times AD=FD\times EA$. Wherefore $BF : AE :: FD : AD$; which is the proposition to be demonstrated.

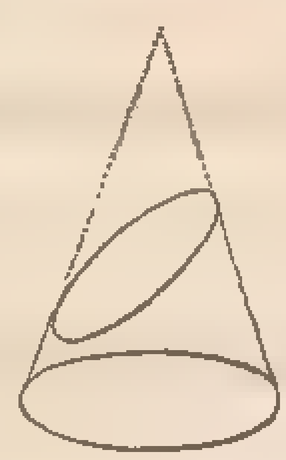
# CONIC SECTIONS.

## DEFINITIONS OF CONIC SECTIONS.

235. A Cone is a solid body, terminating in a point, called its vertex, and having a circle for its base, connected to the vertex by a curved surface, which every where coincides with a straight line passing through its vertex, and through any point in the circumference of the base. If a cone be cut by an imaginary plane, the figure of the section so formed acquires its name according to the inclination or direction of the cutting plane.

236. A plane passing through the vertex of a cone, and meeting the plane of the base, is called a *directing plane*, and the line of common section is called a *directing line*.

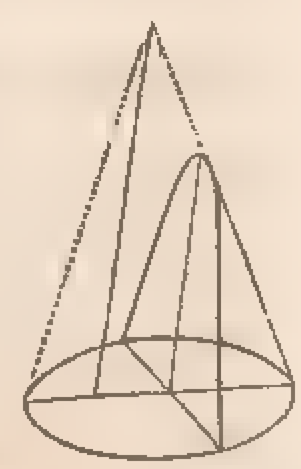
237. If a cone be cut by a plane parallel to the directing plane, the section is denominated a *conic section*.



238. If the directing line fall without the base of the cone, the section is called an *ellipse*.

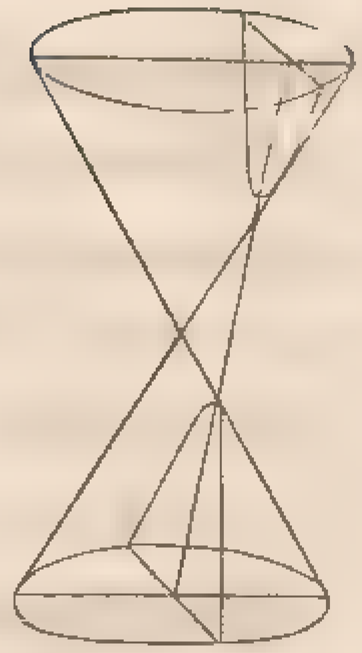
239. If the directing line touch the circumference of the base, the section is called a *parabola*.

240. If the directing line fall within the base, the section is called an *hyperbola*.



241. Equal opposite cones are those which have their axes in the same straight line; and, if cut by a plane through their common line of axis, the sides of the section will be two straight lines cutting each other.

Hence the two equal and opposite cones join each other at their vertices, and have their vertical angles equal.



242. If the plane which produces the section of an hyperbola be extended so as to cut the opposite cone, the two sections are denominated *opposite hyperbolas.*

243. If the plane of a conic section be cut perpendicularly by another plane, which passes through the axis of the cone, the line of common section, in the plane of the figure, is called the *primary line.*

244. A point where the primary line cuts a conic section is called a *vertex* of that conic section.

Hence the ellipse has two vertices, opposite hyperbolas have each one, and the parabola has one.

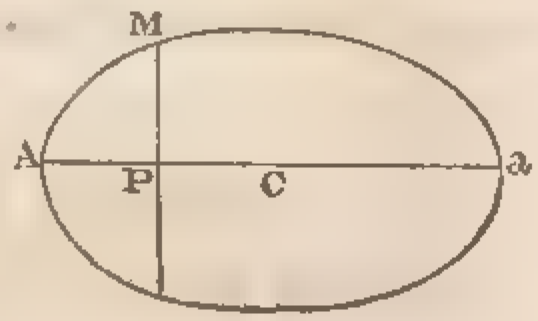
## OF THE ELLIPSE.

245. That portion of the primary line terminated at each extremity by the vertices of the curve, is called the *axis major,* or *transverse axis.*

246. A straight line, drawn perpendicularly to the axis major, from any point in it, to meet the curve, is called an *ordinate.*

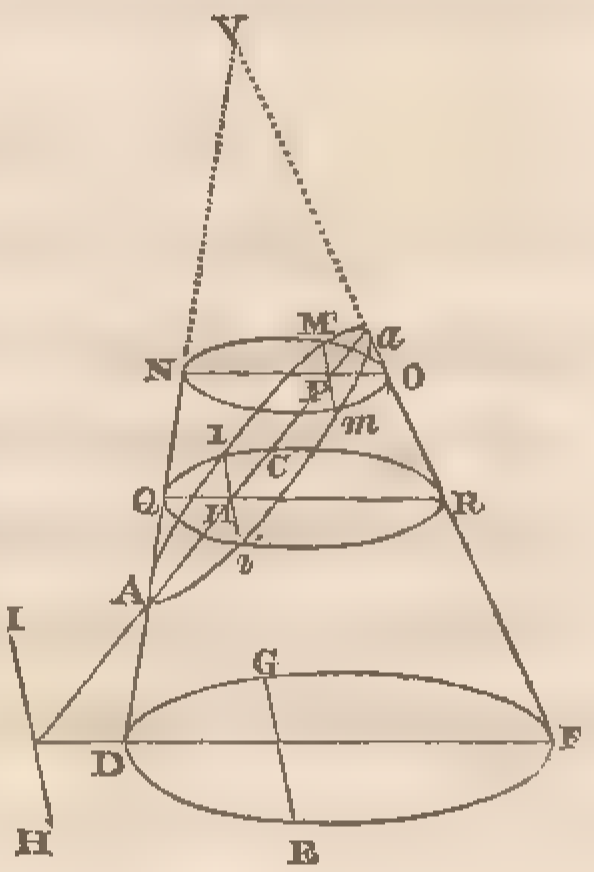
247 The middle of the axis major is called the *centre of the figure.*

In the figure here annexed, Aa is the axis major, PM an ordinate to it, and the point C, in the middle of Aa, is the centre of the ellipse, AMa.




### THE ELLIPSE.—THEOREM 1.

248. The squares of the ordinates of the axis are to each other as the rectangles of the segments of the axis, from each ordinate to each of the two vertices of the curve.




Let VDF be a plane passing through the axis of the cone, perpendicular to the cutting plane of the section A1M*ami*, and let A*a* be their common section, meeting the conic surface in the points A, *a*; (then A*a* will be the axis major,) and let Q1R*i*, NMO*m*, be sections of the cone, parallel to the base. Then, because the base DGFE is perpendicular

to the plane VDF, the three sections, A1M*ami*, Q1R*i*, NMO*m*, are all perpendicular to the plane VDF; therefore their common sections, 1*i*, M*m*, are perpendicular to the plane VDF, and to the lines A*a*, QR, NO; but, because the plane VDF passes through the axis of the cone, it will divide all the circles parallel to the base into two equal parts; therefore QR and NO are the diameters of the circles Q1R*i*, NMO*m*; and, because the chords 1*i*, M*m*, are perpendiculars to the diameters, QR, NO, they will be bisected; let H be the point of bisection in 1*i*, and P the point of bisection in M*m*.

Let $CA = Ca = a$, $CP = x$, $PM = y$, $CH = z$, $HI = \gamma$, $PN = t$, $PO = u$, $HQ = v$, and $HR = w$.

$$\text{Then } AP = CA + CP = a + x, \ aP = Ca - CP = a - x,$$
$$\text{and } AH = CA - CH = a - z, \ aH = Ca + CH = a + z.$$

$$\text{Now, by similar triangles, } \begin{cases} APN, AHQ \ldots v(a+x) = t(a-z) \\ aPO, aHR \ldots w(a-x) = u(a+z) \end{cases}$$

$$\text{and, by the circle, } \ldots\ldots \begin{cases} \ldots\ QIR \ \ldots\ldots \ \gamma^2 = vw \\ \ldots\ NMO \ldots\ldots \ tu = y^2. \end{cases}$$

Wherefore, eliminating $t, u, v, w$, by multiplying the given equations, the result will be $\gamma^2(a+x)(a-x) = y^2(a-z)(a+z)$, or, by actual multiplication, $\gamma^2(a^2-x^2) = y^2(a^2-z^2)$.

249. Corollary 1.—Hence, every chord perpendicular to the axis major is bisected by the axis major.

250. Corollary 2.—Hence the tangents at the extremity of the axis major are perpendicular to the axis major.

### DEFINITIONS RELATIVE TO THE ELLIPSE, CONTINUED.

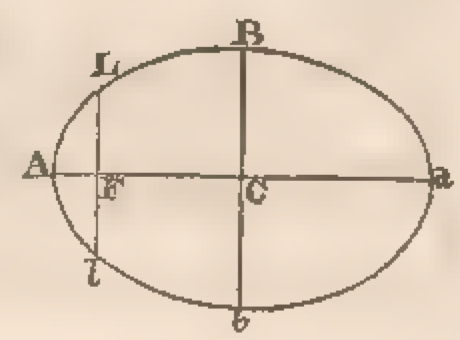
251. A straight line drawn through the centre, perpendicularly to the axis major, and terminated by the curve, is called the *axis minor*, or *conjugate axis*.

252. A third proportional to the axis major and minor, is called the *parameter*, or the *latus rectum* of the axes.

Thus $a$ and $b$ being the semi-transverse and semi-conjugate axes, $2a : 2b :: 2b : p$, the parameter; therefore, $ap = 2b^2$, or if $f = \frac{1}{2}p$, we shall have $af = b^2$, therefore $f = \frac{b^2}{a}$

253. That point in the axis, cut by an ordinate, which is equal to half the parameter, is called the *focus.*

In the figure here annexed, B$b$, drawn through C, is the semi-axis minor; and, if L$l$ be a third proportional to Aa, B$b$, then L$l$ is the parameter, and the point F, where it cuts Aa, is the focus.



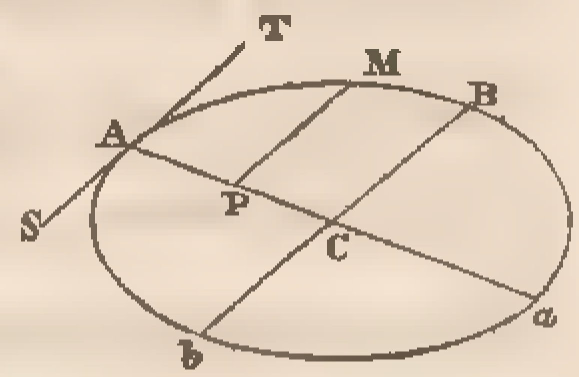

254. Any line drawn through the centre, and terminated at each extremity by the curve, is called a *diameter.*

255. A diameter, which is parallel to a tangent at one extremity of another diameter, is called a *conjugate diameter* to that other diameter.

256. A straight line, parallel to a tangent, at the extremity of any diameter, terminated at one extremity by that diameter and the curve at the other, is called an *ordinate* to that diameter.

257. The portion of a diameter between the centre and an ordinate, is called the *abscissa* of that ordinate, or of that diameter.

In the figure here annexed, the straight line, A$a$, drawn through the centre, C, is a diameter; and, if ST be a tangent at A, and the diameter B$b$ be drawn parallel to ST, the diameter is called the *conjugate diameter* of A$a$; and PM, parallel to ST or B$b$, is an *ordinate* to the diameter A$a$; and the distance CP, on the diameter A$a$, is called the *abscissa.*

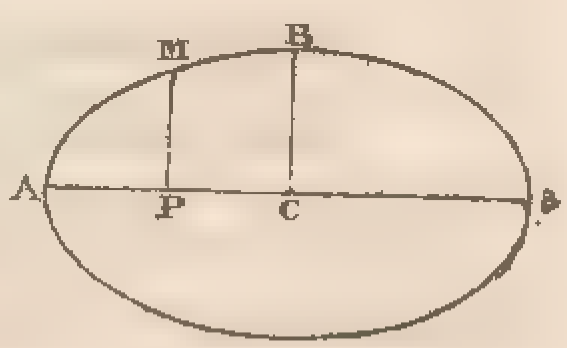



ELLIPSE.—THEOREM 2.

258. The square of the axis major is to that of the axis minor as the rectangle contained by the two parts of the axis major, from the ordinate to each vertex, to the square of the ordinate.

From the preceding theorem, $\gamma^2(a^2-x^2)=y^2(a^2-z^2)$.

Now let $b$ represent the semi-axis minor, and let the ordinate $\gamma$ become $b$, then will its abscissa, $z$, become zero, and, consequently, $\gamma^2(a^2-x^2)=y^2(a^2-z^2)$ will become $b^2(a^2-x^2)=a^2y^2$; whence $a^2:b^2::a^2-x^2:y^2$.

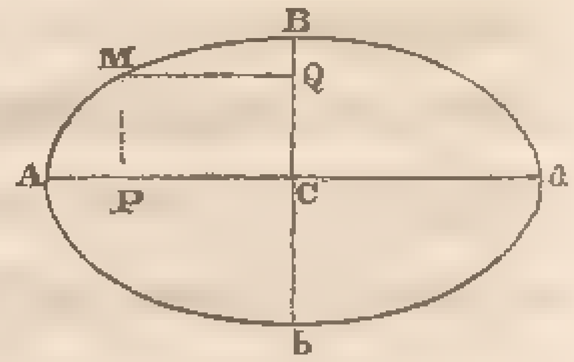


259. Corollary 1.—Hence every ellipse has two focii at an equal distance from the centre; because $y^2 = \frac{b^2}{a^2}(a^2 - x^2)$.

260. Corollary 2.—Hence the tangent at either vertex of the curve is parallel to the ordinates; and, consequently, perpendicular to the axis major.

### ELLIPSE.—THEOREM 3.

261. The square of the axis minor is to that of the axis major as the rectangle contained by the two parts of the axis minor, from the ordinate to the extremity of the axis minor, to the square of the ordinate.

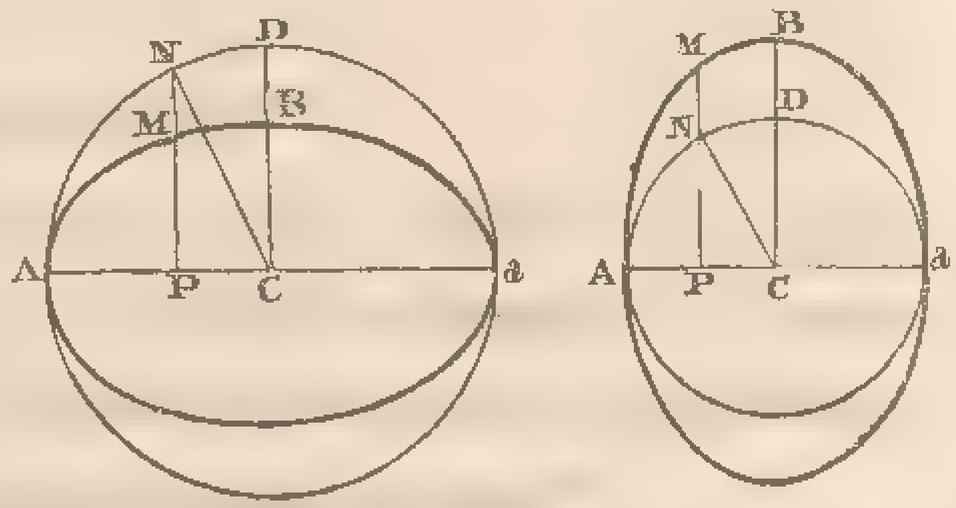



For, by *theorem* 2, ........ $a^2y^2 = b^2(a^2 - x^2)$
and, by transposition, .... $b^2x^2 = a^2(b^2 - y^2)$
therefore, $b^2 : a^2 :: b^2 - y^2 : x^2$.

262. Corollary 1.—Hence the tangent at each extremity of the axis minor is parallel to the ordinates; and, consequently, parallel to the axis major.

263. Corollary 2.—Hence the axis major and minor are reciprocally conjugate diameters.

264. Corollary 3.—If a circle be described on either axis of an ellipse, an ordinate of the circle will be to the corresponding ordinate of the ellipse as the axis of this ordinate is to the other axis.




Let PM cut the inscribed circle in N, and let PM be produced to cut the circumscribing circle in N; in both cases let $\mathrm{CP} = x$, $\mathrm{PM} = y$, $\mathrm{PN} = \gamma$, $\mathrm{CA} = a$, and $\mathrm{CB} = b$.

By *theorem* 2, (258,) .................. $b^2(a^2 - x^2) = a^2y^2$,
and, by the right-angled triangle CPN, ........ $\gamma^2 = a^2 - x^2$.

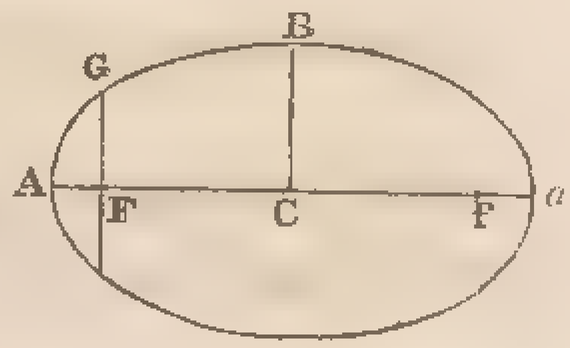
Therefore, multiplying these two equations, we have $b^2\gamma^2 = a^2y^2$, and extracting the root $b\gamma = ay$; wherefore $a : b :: \gamma : y$.

265. Corollary 4.—Hence any two corresponding ordinates of the circle and ellipse are in the same constant ratio of the two axes.

### ELLIPSE.—THEOREM 4.

266. The square of the distance of the focus from the centre is equal to the difference of the squares of the semi-axes.

$$CF^2 = AC^2 - BC^2$$




Let the ordinate FG, which passes through the focus, be denoted by $f$, and CF, the distance of the focus from the centre, by $\varepsilon$.

Then, by the equation of co-ordinates.... $a^2y^2 = b^2(a^2 - x^2)$

and, since (252) AC : BC :: BC : FG, .. $a^2f^2 = b^4$.

Now, in the first of these two equations, when the abscissa $x$ becomes $\varepsilon$, the ordinate $y$ will become $f$, and, consequently, $a^2f^2 = b^2(a^2 - \varepsilon^2)$. Whence $b^4 = b^2(a^2 - \varepsilon^2)$ or $b^2 = a^2 - \varepsilon^2$; and, by transposition, $\varepsilon^2 = a^2 - b^2$.

267. Corollary 1.—Hence, because $af = b^2$, therefore $af = a^2 - \varepsilon^2$.

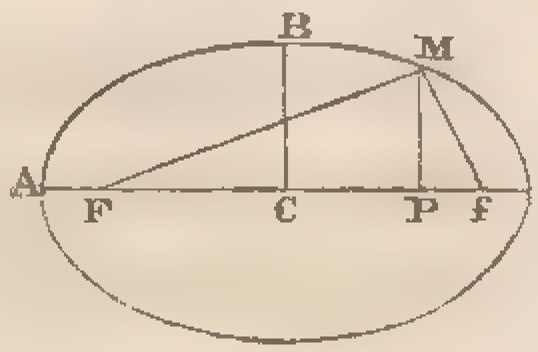
268. Corollary 2.—Hence $b^2 = a^2 - \varepsilon^2 = a^2 - c^2a^2 = a^2(1 - c^2)$.

269. Corollary 3.—Because $a^2y^2 = b^2(a^2 - x^2)$ and that $b^2 = a^2(1 - c^2)$. Therefore, by substitution, there will arise $y^2 = (1 - c^2)(a^2 - x^2) = a^2 - x^2 - c^2a^2 + c^2x^2$.

270. Corollary 4.—The semi-conjugate axis CB is a mean proportional between AF, FB, or between A$f$, $f$B, the distances of either focus from the two vertices, for $b^2 = a^2 - \varepsilon^2 = (a + \varepsilon)(a - \varepsilon)$.

### ELLIPSE.—THEOREM 5.

271. The sum of two lines drawn from the focii, to meet any point in the curve, is equal to the transverse axis.




Let $FM = R$, $fM = r$, $FC = fC = \varepsilon = ca$.

Then will $FP = CF + CP = ca + x$,

and ..... $fP = Cf - PC = ca - x$.

By Geom. (160).... $FM^2 = PM^2 + FP^2$, $R^2 = y^2 + c^2a^2 + 2cax + x^2$,

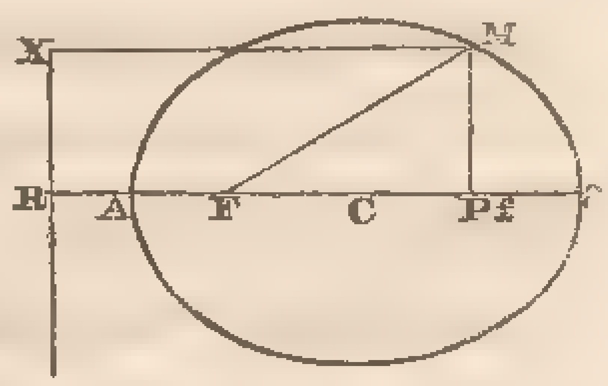
and, by *theorem* 4, *cor.* 3, ............ $y^2 = a^2 - c^2a^2 + c^2x^2 - x^2$.

Wherefore, eliminating $y$, by adding these equations together, we have the equations.............................. $R^2 = a^2 + 2cax + c^2x^2$.

Then, extracting the roots of each side of this equation, we have $R = a + cx$. In the same manner will be found $r = a - cx$; therefore $R + r = 2a$.

272. Corollary 1.—Hence $R = a + \frac{\varepsilon}{a}x$, and $r = a - \frac{\varepsilon}{a}x$, for $\varepsilon = ca$ or $c = \frac{\varepsilon}{a}$.

273. Corollary 2.—Because $R = a + \frac{\varepsilon}{a}x$, we shall have $aR = a^2 + \varepsilon x$; and, by transposition, $a(R - a) = \varepsilon x$, hence $R - a : x :: \varepsilon : a$.




274. Corollary 3.—Since the ratio of $\varepsilon$ to $a$, or that CF to CA is constant, if we produce $a$A to R, and find the point R by making CF : CA :: CA : CR, and draw RX perpendicular to $a$R, and MX parallel to $a$R, and let CR$=d$; then will $R - a : x :: a : d$; wherefore $Rd - ad = ax$, or, by transposition, $Rd = ad + ax = a(d + x)$. Therefore $d + x : R :: d : a$; wherefore MX is to MF always in the constant ratio of CR to CA; and hence we have another method of constructing the ellipse.

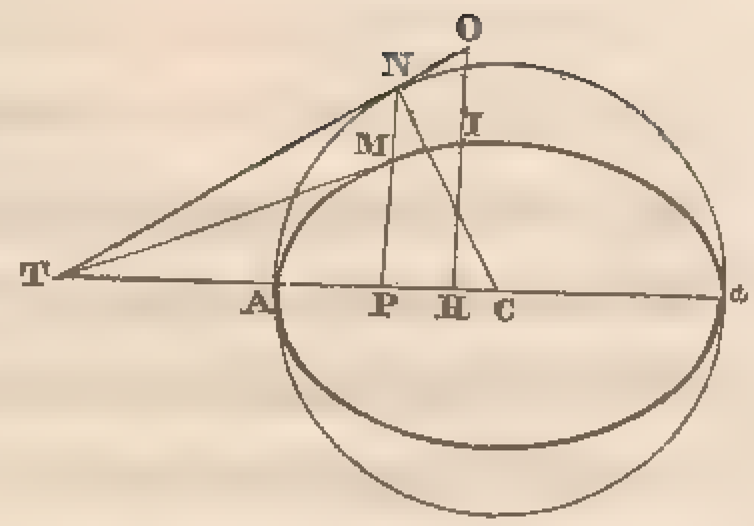
N.B. The line RX is called the directrix. Several writers make this the fundamental principle from which all the other properties emanate.

275. Corollary 4.—Hence CR : CA :: $a$R : $a$F; because, when the point M comes to $a$, the line MX or PR will become $a$R, and the radius vector, FM, will become F$a$.

276. Corollary 5.—Hence CA : CF :: $a$R : $a$F.

### ELLIPSE.—THEOREM 6.

277. The tangents from the corresponding points in the curves of a circle and ellipse, made by the prolongation of an ordinate of the ellipse, will meet the axis major produced in the same point T.




Let AN$a$ be a circle described upon the axis major, and let PN be a tangent to the circle in N. Join TM; then, if TM does not touch the ellipse, let it cut it in M, I; and, through I, draw the ordinate HO, meeting the ellipse in I, the circle in L, and the tangent in O.

By similar triangles .... $\begin{cases} \text{TPM}, \text{THI} \text{ .......... } \text{TP} \times \text{HI} = \text{PM} \times \text{TH} \\ \text{TPN}, \text{THO} \text{ .......... } \text{PN} \times \text{TH} = \text{TP} \times \text{HO} \end{cases}$

and, by *theorem* 3, *cor*. 4, .. PN : PM :: HL : HI $\therefore$ PM $\times$ HL $=$ PN $\times$ HI.

Therefore, by multiplication, we shall find HL $=$ HO, which is impossible; therefore TM does not cut the ellipse, and it must, in consequence, be a tangent at M.

### ELLIPSE.—THEOREM 7.

278. In the straight line, T$a$, of the axis major, the semi-axis, CA, is a mean proportional between the abscissa, CP, and the distance, CT, from the centre to the intersection of the tangent.

For the triangle CNT (see the preceding diagram) is right-angled at N, since PN meets the circle at N; and, because PN is perpendicular to TC, we shall have,

by the similar triangles PCN, NCT, .... $\text{CP} \times \text{CT} = \text{CN}^2$

and by the circle ...................... .. $\text{CN}^2 = \text{CA}^2$.

Therefore, by multiplication, $\text{CP} \times \text{CT} = \text{CA}^2$.

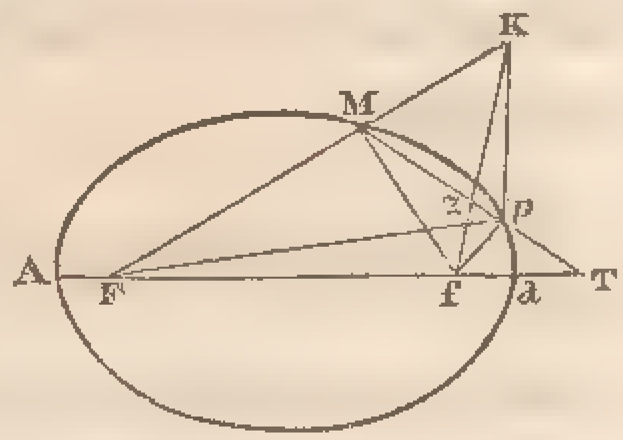
If CT$=u$, this conclusion, analytically expressed, is $ux=a^2$; or, if $s$ be the subtangent, then will $u=s+x$; and, therefore, $(s+x)x=a^2$, that is, $sx+x^2=a^2$.

279. Corollary 1.—Whence, if $z$ be any other abscissa, and S its subtangent, and if $s+z=v$, then $vz=a^2$; and, since $ux=a^2$, therefore $ux=vz$.

280.—Corollary 2.—When the abscissa becomes equal to the excentricity, $x$ becomes $\varepsilon$; and, consequently, $ux=a^2$ becomes $u\varepsilon=a^2$, or $\text{S}\varepsilon+\varepsilon^2=a^2$.

### ELLIPSE.—THEOREM 8.

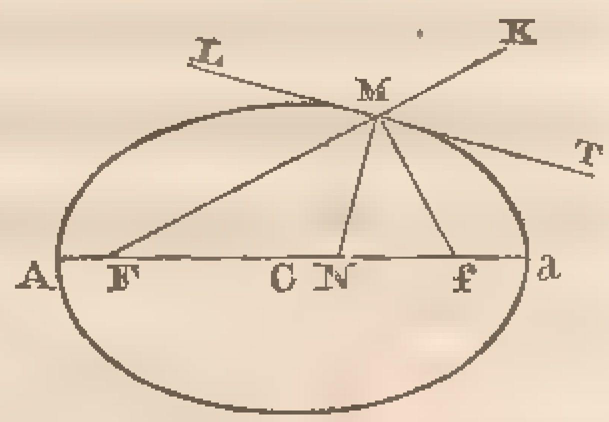
281. The line bisecting the angle at any point in the curve, formed by one of the lines drawn from one of the focii, and the prolongation of the line drawn from the other focus, will be a tangent to the curve.




Let MT bisect the angle $f$MK; then, if MT is not a tangent, it will cut the ellipse; let $p$ be the point where it meets the curve, and, making MK=M$f$, join $f$K, $fp$, F$p$, K$p$, and let MT cut K$f$, in $z$.

Then, in the triangles $f$M$z$, KM$z$, $f$M being =KM, M$z$ common, and the included angles $f$M$z$, KM$z$, equal; the base $fz$ is =K$z$, and the angle $fz$M=K$z$M.

Again, in the triangles $fpz$, K$pz$, $fz$ being =K$z$, $pz$ common, and the angles $fzp$, K$zp$, equal, the base $fp$ is =K$p$. Therefore F$p$+$p$K=F$p$+$pf$= FM+M$f$=FM+MK=FK; wherefore the sum of the two sides, F$p$, $p$K, of the triangle F$p$K, is equal to the third FK; which is impossible; therefore as MT cannot cut the ellipse: it must be a tangent.

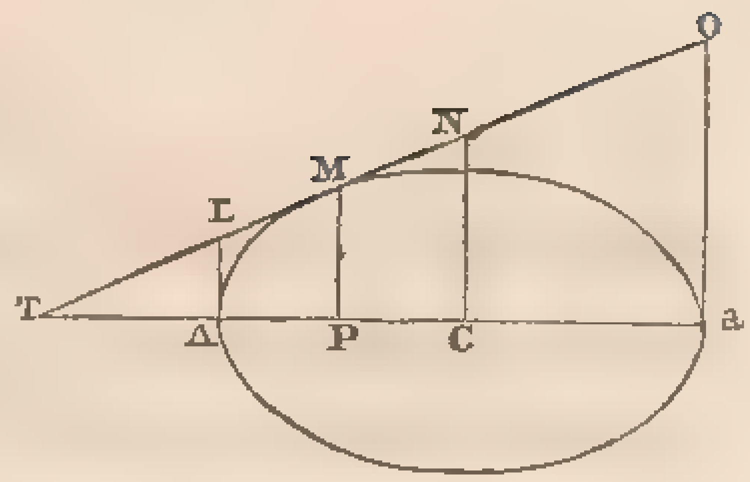



282. Corollary.—Hence, because the angle KM$f$ is bisected, the angle FM$f$ will also be bisected by the normal MN. For since the angle TM$f$ is =TMK, and TMK equal to the opposite angle FML; therefore TM$f$ is = FML: and, because the angles TMN and LMN are each a right angle; therefore, taking away the angles TM$f$, LMF, which are equal, from the right angles TMN, LMN, there will remain the angle NM$f$ equal to the angle NMF.

### ELLIPSE.—THEOREM 9.

283. If there be any tangent meeting the four perpendiculars to the transverse axis, the one at the extremity of the transverse, next to the point of intersection, will be to that which terminates in the point of contact, as that which passes through the centre is to the remaining one at the other extremity of the transverse.

$$AL : PM :: CN : aO$$

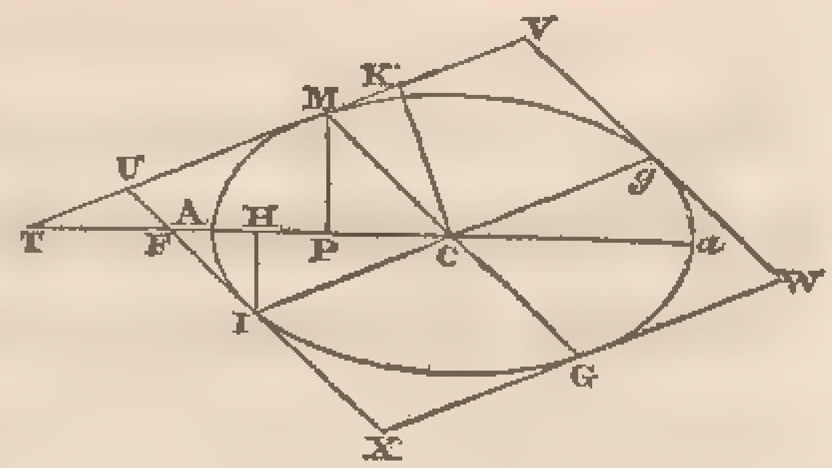



Let AL$=k$, PM$=l$, CN$=m$, and $a$O$=n$. Then, if we can show that the distances TA, TP, TC, T, are four proportionals, AL, PM, CN, $a$O, being the homologous sides of similar triangles, will likewise be proportionals.

By *theorem* 7, (278,) $sx+x^2=a^2$; therefore, by transposition, $sx+x^2-a^2=o$; to each side of this equation add $s^2+sx$, and we have $s^2+2sx+x^2-a^2=s^2+sx$; that is, because $s^2+2sx+x^2$ is a complete square, and that $s^2+sx=s(s+x)$ $(s+x)^2-a^2=s(s+x)$, that is, $(s+x+a)(s+x-a)=s(s+x)$. Whence $s+x-a : s :: s+x : s+x+a$.

### ELLIPSE.—THEOREM 10.

284. Every parallelogram, UVWX, circumscribing an ellipse, having its sides parallel to two conjugate diameters, is equal to the rectangle of the two axes.




If tangents be drawn at the extremities of two conjugate diameters, they form an ellipse, of which CMUI is a fourth part.

Draw CK, perpendicular to MT. Let C$t=v$, TM$=t$, CI$=n$, CT$=u$, CK$=p$, PT$=s$.

By *theorem* 7, (278) .................. $a^2-x^2=sx$

and by *theorem* 7, *cor*. 1, (279) .......... $ux=vz$

and by similar triangles $\begin{cases} t\text{CI, CTM} \ldots\ldots & vt=nu \\ \text{ICH, MTP} \ldots\ldots & ns=tz \end{cases}$

and by *theorem* 2, (258) ................ $a^2\gamma^2=b^2(a^2-z^2)$

and by similar triangles, TCK, CIH .... $p^2n^2=u^2\gamma^2$

and by *theorem* 7, (278,) ................ $u^2x^2=a^4$.

For, multiplying the first four equations, $a^2-x^2=z^2$; or, by transposition, $a^2-z^2=x^2$. Multiply this and the three remaining equations and $pn=ab$.

285. Corollary.—Hence $a^2=x^2+z^2$, and $b^2=y^2+\gamma^2$.

### ELLIPSE.—THEOREM 11.

286. The sum of the squares of any pair of conjugate diameters is equal to the sum of the squares of the two axes.

Let CM$=m$, CI$=n$. See the preceding figure.

By *theorem* 10, *cor.* (285) ... .. ..... $\begin{cases} \ldots a^2 = x^2 + z^2 \\ \ldots b^2 = y^2 + \gamma^2 \end{cases}$

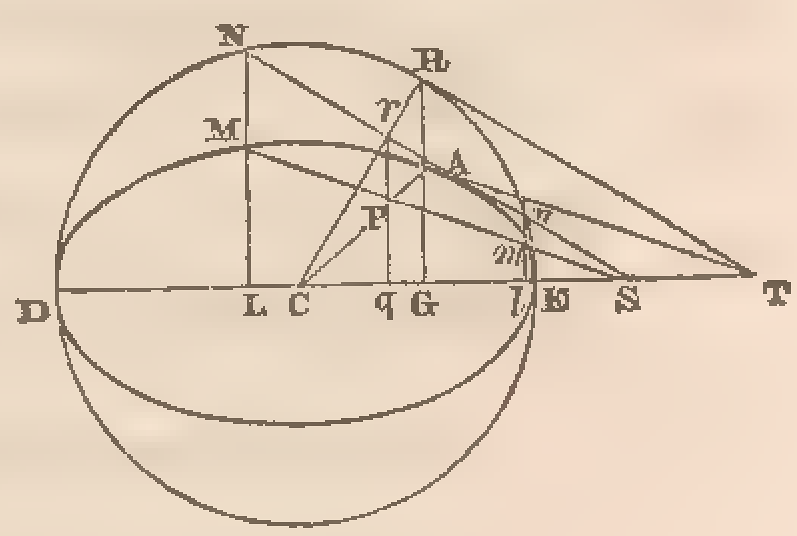
and by *Geometry*, (160) ............ $\begin{cases} x^2 + y^2 = m^2 \\ z^2 + \gamma^2 = n^2. \end{cases}$

Therefore, by adding these together, we have $a^2 + b^2 = m^2 + n^2$.

*N.B. All these theorems concerning the Ellipse, and their demonstrations, are in the very same words as the corresponding number of those for the Hyperbola, next following; having sometimes only the word* sum *changed for the word* difference.

### ELLIPSE.—THEOREM 12.

287. If a chord be bisected, the tangent at the extremity of the diameter, passing through the point of bisection, will be parallel to that chord.




Through M, $m$, draw LN, $ln$, to meet the circumference of the circle described on the axis DE, in the points, N, $n$. Produce M$m$ and DE, to meet each other in S, and join S$n$, SN, and let the chord M$m$ be bisected in P.

Then, because S$l$ : $lm$ :: SL : LM

and ........ $lm$ : $ln$ :: LM : LN

therefore eliminating LM, $lm$, .... S$l$ : $ln$ :: SL : LN.

Therefore S$n$ and SN are in a straight line. Through P draw $qr$, meeting DE in $q$, and N$n$ in $r$; then N$n$ is bisected in $r$. Join C$r$, and produce it to meet the circumference in R, and draw the tangent RT, meeting DE produced in T; then RT is parallel to NS. Draw RG, perpendicular to DE, meeting DE in G, and CA in A.

$$\begin{aligned} \text{Then, because } LN : LM &:: qr : qP \\ qr : qP &:: GR : GA \\ \text{therefore} \ldots\ldots LN : LM &:: GR : GA \end{aligned}$$

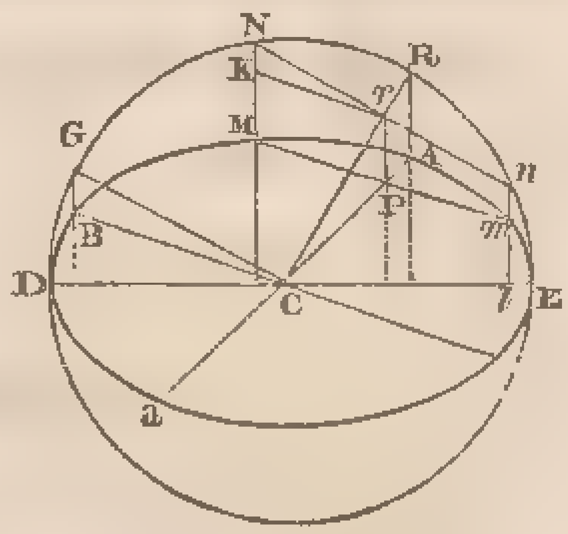
And, therefore, the point A is in the curve of the ellipse. Then drawing AT, AT is a tangent by the preceding proposition.

$$\begin{aligned} \text{Now, because } CR : Cr &:: CT : CS \\ \text{and} \ldots\ldots\ldots CR : Cr &:: CA : CP \\ \text{therefore} \ldots CT : CS &:: CA : CP. \end{aligned}$$

Therefore AT is parallel to M*m*.

### ELLIPSE.—THEOREM 13.

288. The rectangle of the squares of any semi-diameter, and of an ordinate to it, is equal to the rectangle of the square of the semi-conjugate and the difference of the squares of the semi-diameter of the abscissa, and of the abscissa itself.




$$CA^2 \times PM^2 = BC^2 \times (CA^2 - CP^2).$$

Draw $rK$ parallel to PM, cutting MN in K, and draw CG parallel to N$n$, cutting the circumference in G, and CB parallel to PM, cutting the ellipse in B, and join BG.

Let $CR=r$, $Cr=u$, $rN=rn=v$, $CA=a$, $CB=b$, $CP=x$, $PM=rK=y$.

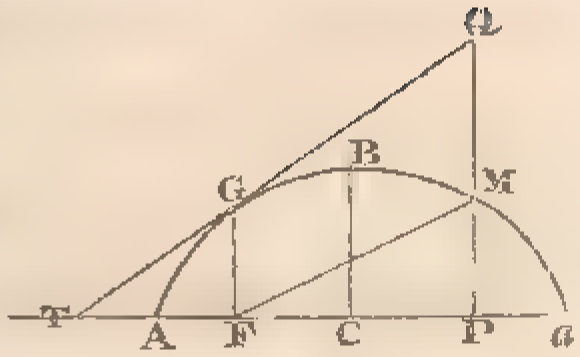
By the equation of the circle ................. $v^2=r^2-u^2$

By similar triangles, $\begin{cases} BCG,\ KrN \ldots\ldots\ldots r^2y^2=b^2v^2 \\ ACR,\ PCr \ldots\ldots\ldots rx^2=a^2u^2. \end{cases}$

Multiply the first and second equations together, and $r^2y^2=b^2r^2-b^2u^2$; or, by transposition, $b^2u^2=r^2(b^2-y^2)$. Multiply this and the third equation, and $b^2x^2=a^2(b^2-y^2)$; or, by transposition, $a^2y^2=b^2(a^2-x^2)$.

### ELLIPSE.—THEOREM 14.

289. The semi-ordinate, together with its prolongation to meet a tangent at the extremity of a *latus rectum,* is equal to the *radius vector* through the same focus with that of the latus rectum.




$$FM = PQ.$$

Let $CT = u$, $PQ = v$, $PT = w$, and $FT = q$.

Then will $FT = CT - CF = u - \varepsilon = q$

and..... $PT = CT + CP = u + x = w$.

By notation ..................... $\begin{cases} u - \varepsilon = q \\ w = u + x \end{cases}$

and by *theorem* 7, *cor.* 2,............... $u\varepsilon = a^2$

and by *theorem* 4, *cor.* 1,............... $af = a^2 - \varepsilon^2$

and by similar triangles, TPQ, TFG,.... $qv = fw$.

Multiply the first and second of these equations by $\varepsilon$, and the results are $u\varepsilon - \varepsilon^2 = \varepsilon q$, and $w\varepsilon = u\varepsilon + \varepsilon x$. In each of these two equations, for $u\varepsilon$ substitute its equal $a^2$ from the second, and we have $a^2 - \varepsilon^2 = \varepsilon q$ and $w\varepsilon = a^2 + \varepsilon x$. Multiply these two equations, and the remaining two of the given equations, and the final result is $av = a^2 + \varepsilon x$, therefore $v = a + \frac{\varepsilon}{a}x$.

But, by *theorem* 5, we have $R = a + \frac{\varepsilon}{a}x$, therefore $R = v$.

## OF THE HYPERBOLA.

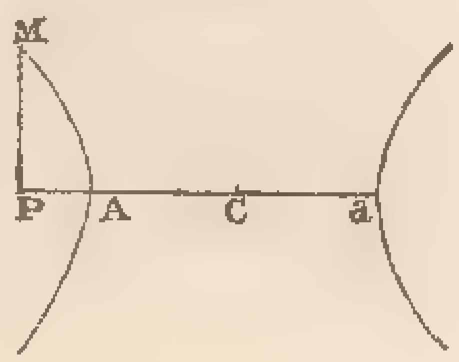
### DEFINITIONS RELATIVE TO THE HYPERBOLA.

290. That portion of the primary line between the vertices of the two opposite curves, is called the *transverse axis.*

291. A straight line, drawn perpendicularly to the transverse axis, between the transverse axis and the curve, is called an *ordinate.*

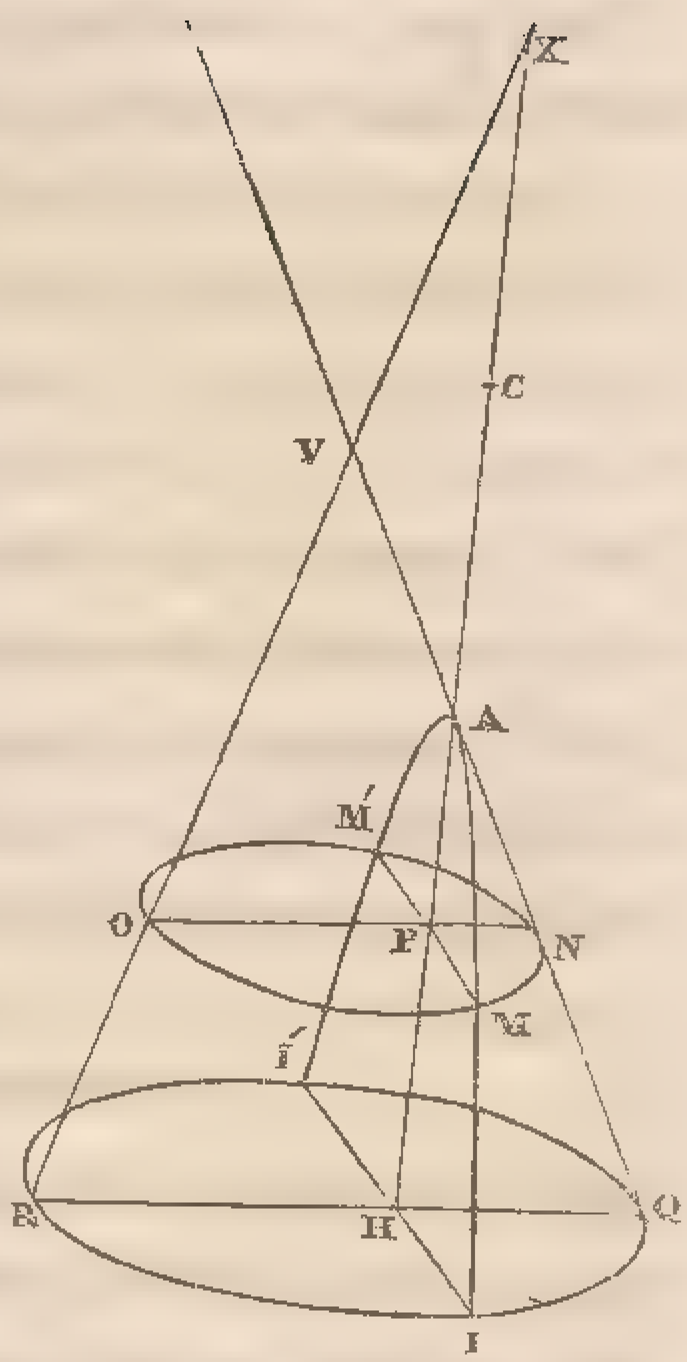
292. The middle of the transverse axis is called the *centre of the figure.*

293. In the annexed diagram, Aa is the transverse axis, C, the middle of Aa, the centre; PM the ordinate, and CP the abscissa.




### HYPERBOLA.—THEOREM 1.

294. The squares of the ordinates of the axis are to each other as the rectangles of the two segments of the axis, from each ordinate to each of the two vertices of the opposite curves.




Let VRQ, passing through the common line of axis of two opposite cones, be a plane perpendicular to the cutting plane of the opposite sections; and let AMII′M′ be one of the sections, HA the common line of section of the two planes, and let HA cut the two conic surfaces in A, X; then AX will be the primary axis; and let OMNM′ be a section of the cone parallel to its base, RIQI′.

Because the plane of the base, RIQI′, is perpendicular to the plane VRQ, the plane OMNM′ will also be perpendicular to the plane VRQ; and, since each of the two planes AMII′M′, RIQI′, and AMII′M′, OMNM′, are perpendicular to the plane VRQ, their common sections II′, MM′, are perpendicular to the plane VRQ; therefore II′, MM′, are perpendicular to the lines RQ, ON, AH, in the plane VRQ; and, because the plane VRQ passes through the axis of the cone, it will divide all the circles parallel to the base into two equal parts; therefore RQ, ON, will be diameters of the two circles; and, since the chords II′, MM′, are at right angles to the diameters RQ, ON, the chords II′, MM′, will be bisected in H and P. Therefore HI=HI′, and PM=PM′.

Let $CA=CX=a$, $CP=CX=x$, $PM=y$, $CH=z$, $HI=\gamma$, $PN=t$, $PO=u$, $HQ=v$, and $HR=w$.

$$\begin{aligned} \text{Then } AP &= CP-CA=x-a,\\ XP &= CP+CX=x+a,\\ AH &= CH-CA=z-a,\\ \text{and } XH &= CH+CX=z+a. \end{aligned}$$

$$\text{Now, by similar triangles, } \begin{cases} APN,\ AHQ\ldots (x-a)v=t(z-a)\\ XPO,\ XHR\ldots (a+x)w=u(z+a) \end{cases}$$

$$\text{and, by the circle, }\ldots\ldots \begin{cases} \ldots\ QIRI'\ldots\ldots\ \gamma^2=vw\\ \ldots\ NMOM'\ldots\ tu=y^2. \end{cases}$$

Therefore, eliminating $t$, $u$, $v$, $w$, by multiplying the given equations, there will result $\gamma^2(x-a)(x+a)=y^2(z-a)(z+a)$, or, by actual multiplication, $\gamma^2(x^2-a^2)=y^2(z^2-a^2)$; therefore $\gamma^2 : y^2 :: (z-a)(z+a) : (x-a)(x+a)$.

295. Corollary 1.—Hence $\frac{\gamma^2}{z^2-a^2}=\frac{y^2}{x^2-a^2}$ is a constant quantity.

296. Corollary 2.—Hence if $z$ be made constant, $\gamma$ will be constant also. Therefore, when $z^2-a^2$ becomes $a^2$, let $\gamma=b$, and, consequently, $\frac{b^2}{a^2}=\frac{y^2}{x^2-a^2}$.

297. Corollary 3.—Hence every chord, perpendicular to the transverse axis, is bisected by the same axis.

298. Corollary 4.—Hence the tangent at the extremity of the transverse axis is bisected by the transverse axis.

299. Corollary 5.—Hence $ay^2=b^2(x^2-a^2)=b^2x^2-a^2b^2$.

### HYPERBOLA.—DEFINITIONS, CONTINUED.

300. The constant value $b$ of $\gamma$, when $z^2-a^2$ becomes $a^2$, is called the *semi-conjugate axis*, or twice $b$ the *conjugate axis*.

301. A third proportional to the transverse and conjugate axes, is called the *parameter*, or *latus rectum*.

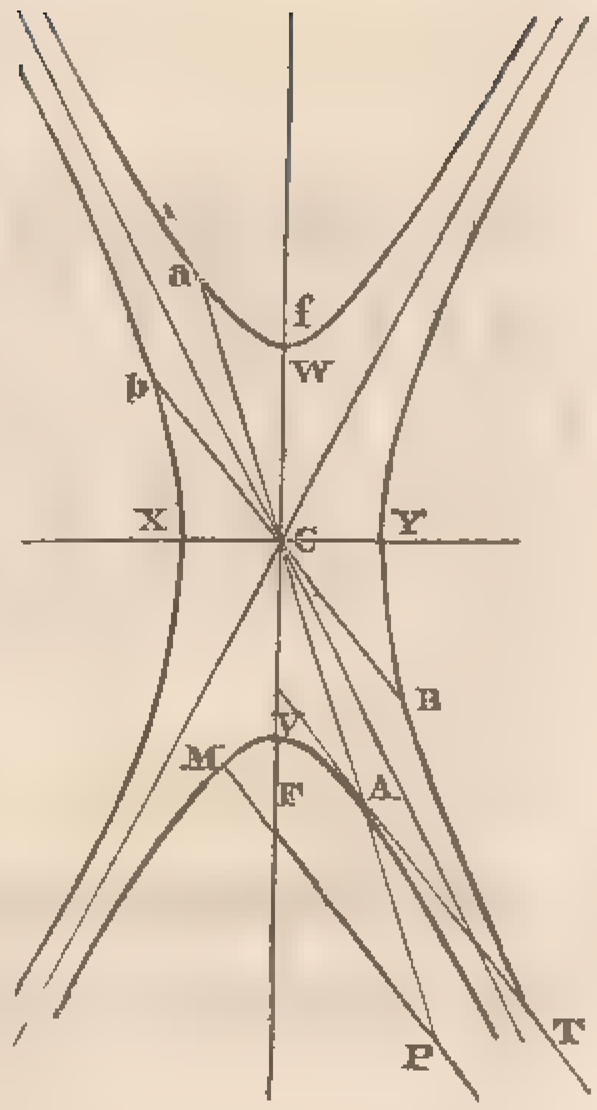
Thus $a$ and $b$ being the semi-transverse and semi-conjugate axes, $2a:2b::2b:p$, the parameter; therefore, $ap=2b^2$, or if $f=\frac{1}{2}p$, we shall have $af=b^2$, therefore $f=\frac{b^2}{a}$

302. That point in the axis cut by an ordinate which is equal to half the parameter is called the *focus*.

303. If there be two opposite hyperbolas, and two others having the same centre, and their common line of axis at right angles to that of the two former, the transverse equal to the conjugate of the two former, and the conjugate equal to the transverse of the two former; these four hyperbolas are called *conjugate hyperbolas*.

304. Any straight line, drawn through the centre, and terminated by opposite curves, is called a *diameter*.

A diameter which is parallel to a tangent, at the extremity of another diameter, is called a *conjugate diameter* to that other diameter.

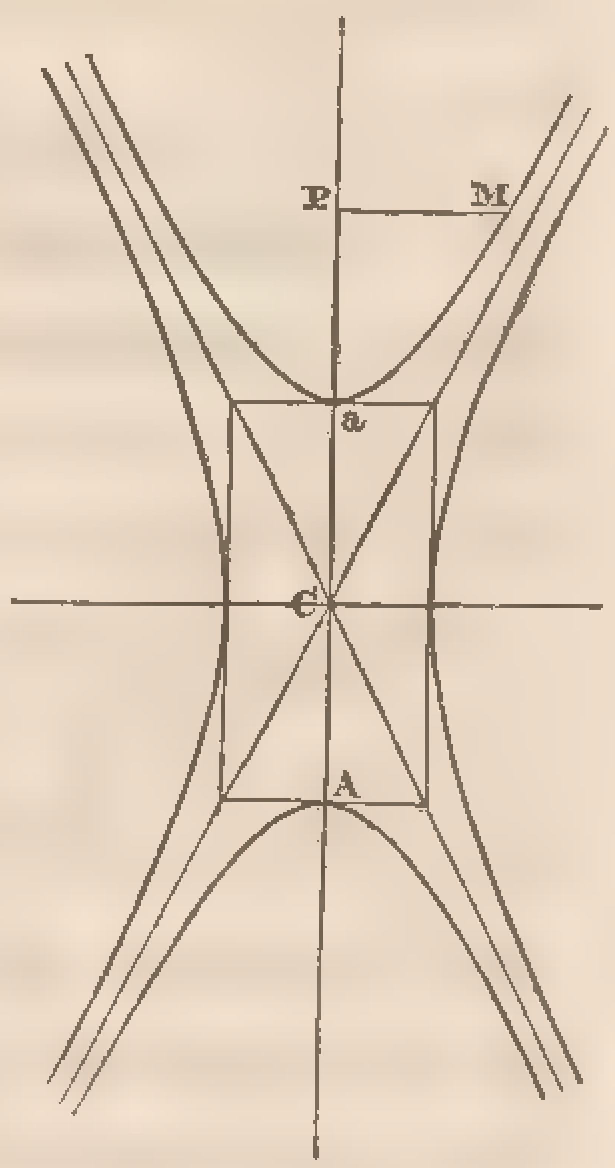



305. A straight line, parallel to a tangent, meeting the diameter in one extremity, and the curve in the other, is called an *ordinate* to that diameter.

306. The distance between the centre and an ordinate is called the *abscissa.*

In the diagram here annexed, the straight line Aa, drawn through the centre, C, is a diameter; and, if AT is a tangent at A, then Bb, parallel to AT, passing through the centre C, is the conjugate diameter; PM parallel to AT, is the ordinate to Aa, and CP is the abscissa.

HYPERBOLA.—THEOREM 2.




307. The square of the transverse axis is to the square of the conjugate axis as the rectangle of the two distances from the ordinate to the vertex of each curve.

$$CA^2 : CB^2 :: PA \times Pa : PM.$$

For $\frac{b^2}{a^2} = \frac{y^2}{x^2 - a^2} = \frac{y^2}{(x-a)(x+a)}$

Therefore $a^2 : b^2 :: (x-a)(x+a) : y^2$.

308. Corollary 1.—Hence every pair of opposite hyperbolas has two focii at an equal distance from the centre; because $y^2 = \frac{b^2}{a^2}(a^2 - x^2)$: and, since the origin of the abscissa commences at the centre, therefore the ordinate $y$ must be the same at the same distance on each side of the centre.

309. Corollary 2.—Hence the tangent at the vertex of either curve is parallel to the ordinates, and, consequently, perpendicular to the transverse axis.

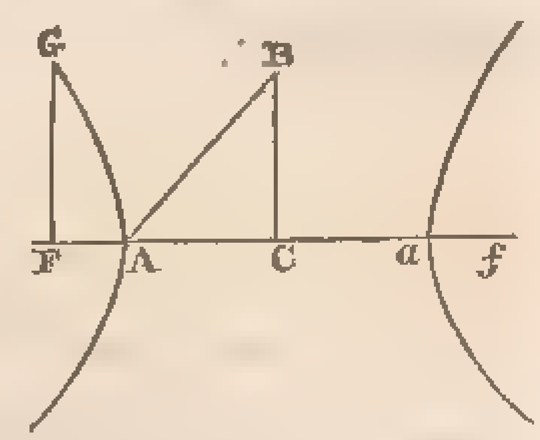
### HYPERBOLA.—THEOREM 3.

310. The square of the conjugate axis is to the square of the transverse axis, as the sum of the squares of the semi-conjugate axis; and that of the ordinate is to the square of the abscissa as $CB^2 : CA^2 :: CB^2 + PM^2 : CP^2$.

For, (*theorem* 2,) $a^2y^2 = b^2x^2 - a^2b^2$; and, therefore, by transposition, $a^2(y^2+b^2) = b^2x^2$, consequently, $b^2 : a^2 :: y^2+b^2 : x^2$. (See *figure, theorem* 2.)

### HYPERBOLA.—THEOREM 4.

311. The square of the distance of the focus from the centre is equal to the sum of the squares of the two axes.




$$CF^2 = AC^2 + BC^2$$

Let the ordinate FG, which passes through the focus, be denoted by $f$, and CF, the distance of the focus from the centre, by $\varepsilon$.

Then, by the equation of the co-ordinates, .. $a^2y^2 = b^2(x^2 - a^2)$.

And, since (301) ........................ $a^2f^2 = b^4$.

Now, in the first of these equations, when the abscissa $x$ becomes equal to $\varepsilon$, the ordinate $y$ will become $f$; and, consequently, $a^2f^2 = b^2(\varepsilon^2 - a^2)$; whence, $b^4 = b^2(\varepsilon^2 - a^2)$ or $b^2 = \varepsilon^2 - a^2$, and, by transposition, $\varepsilon^2 = a^2 + b^2$.

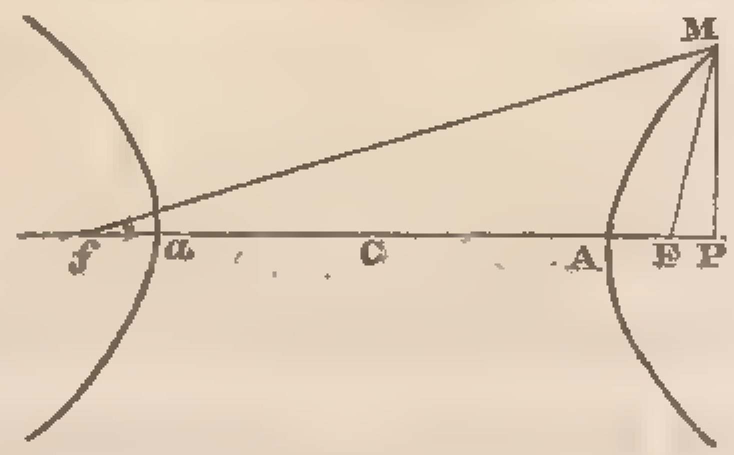
312. Corollary 1.—The two semi-axes, and the distance of a focus from the centre, are the sides of a right-angled triangle, ACB, and the hypothenuse, AB, is equal to the distance of the focus from the centre.

313. Corollary 2.—The conjugate axis, CB, is a mean proportional between AF and F$a$, or $fa$, $f$A, the distances between either focus and the two vertices; for $b^2 = \varepsilon^2 - a^2 = (\varepsilon - a)(\varepsilon + a)$.

314. Corollary 3.—Hence, if $\varepsilon = ca$, then will $y^2 = a^2 - x^2 + c^2x^2 - c^2a^2$; for, (*theorem* 2,) $a^2y^2 = b^2(x^2 - a^2)$. But, by this theorem, we have $b^2 = \varepsilon^2 - a^2$; then, multiplying these two equations, we have $a^2y^2 = (\varepsilon^2 - a^2)(x^2 - a^2)$; or, substituting $ca$ for $\varepsilon$, we shall have $y^2 = (c^2 - 1)(x^2 - a^2) = a^2 - x^2 + c^2x^2 - c^2a^2$.

### HYPERBOLA.—THEOREM 5.

315. The difference of two lines, drawn from the focii to meet any point in the curve, is equal to the transverse axis.




Let $FM=R$, $fM=r$, $FC=fC=e=ca$.
Then will $FP=CP+CF=x+ca$,
and ..... $fP=CP-Cf=x-ca$.

By Geometry, (*prop.* 62,) .. $FM^2=PM^2+FP^2$, $R^2=y^2+x^2+2acx+c^2a^2$.

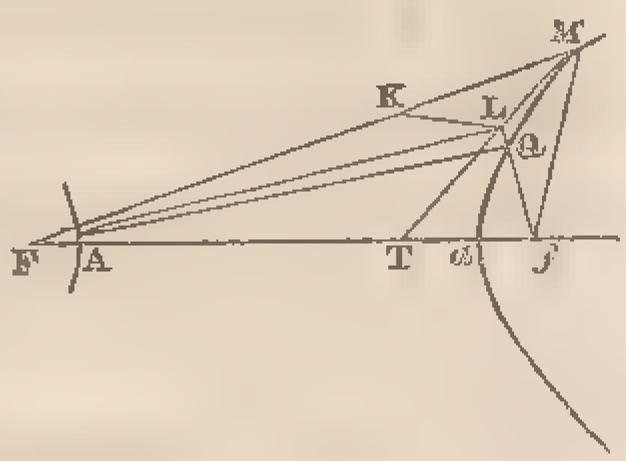
And, by *theorem* 4, *cor.* 3, (314) ........... $y^2=a^2-x^2+c^2x^2-c^2a^2$,

wherefore, eliminating $y$, by adding these equations together, we have the equation ................................. $R^2=c^2x^2+2acx+a^2$.

then, extracting the roots of each side of this equation, we have $R=cx+a$ $=\frac{e}{a}x+a$. In like manner will be found $r=cx-a=\frac{e}{a}x-a$; therefore $R-r=2a$.

### HYPERBOLA.—THEOREM 6.

316. The line bisecting the angle, at any point in the curve formed by the two lines drawn from that point to each focus, is a tangent.




The tangent MT at M will bisect the angle $FMf$.

In MF take $MK=Mf$, and in MT take any point L; join $fL$, and let it meet the curve in Q; join also KL, FL, FQ. Then, by hypothesis, the angle $KML=fML$, $KM=fM$, and LM is common, the base LK is $=Lf$; but the difference of any two sides of a triangle is less than the third;* therefore $FL-LK$, or $FL-Lf$, is less than FK, or $Ff$, or $FM-fM$, or $FQ-fQ$. Hence $fL$ is greater than $fQ$; for, since $FL-fL$ is less than $FQ-fQ$, if $fL$ were less than $fQ$, $FL+LQ$

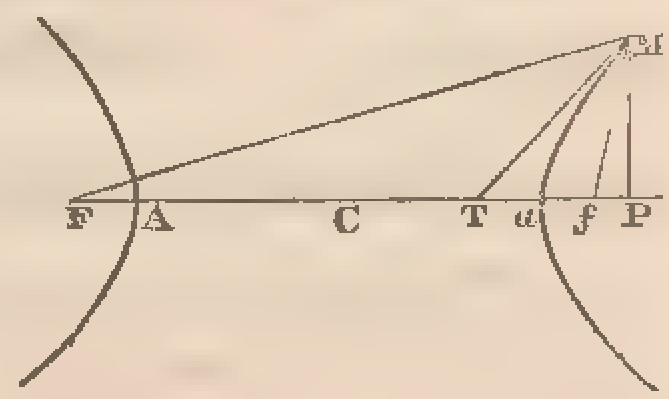
* It is shown by every writer of Elementary Geometry, that the sum of every two sides of a triangle are greater than the third. Let $a$, $b$, $c$, be the three sides of a triangle; then, $a+b$ ⌐ $c$, $a+c$ ⌐ $b$, $b+c$ ⌐ $a$: therefore, by transposition, $a$ ⌐ $c-b$, $a$ ⌐ $b-c$, $b$ ⌐ $c-a$, $b$ ⌐ $a-c$, $c$ ⌐ $b-a$, $c$ ⌐ $a-b$.

N.B. ⌐ signifies *greater than.*

would be less than FQ; which is impossible. Therefore every point, L, in MT, except M, is without the curve of the hyperbola; and MT touches it at M.

### HYPERBOLA.—THEOREM 7.

317. In the line of the axis major, the rectangle contained by the distance between the centre and the intersection of the tangent, and the distance between the centre and the ordinate, is equal to the square of the semi-axis major.




Let $CT = u$.

Then will $FT = CF + CT = \varepsilon + u$.

and .... $fT = Cf - CT = \varepsilon - u$.

By *theorem* 5, (315,) ............... $\begin{cases} R = \frac{\varepsilon}{a}x + a \\ \frac{\varepsilon}{a}x - a = r \end{cases}$

and by Geometry, (*theorem* 57,) .... $r(\varepsilon + u) = R(\varepsilon - u)$.

Multiplying these three equations together, we have $ux = a^2$.

### HYPERBOLA.—THEOREM 8.

318. The semi-transverse axis is a mean proportional between the two distances in the line of the transverse axis; the one from the centre to the ordinate, and the other from the centre to the intersection of the tangent.

For, by the preceding proposition, $ux = a^2$, therefore $x : a :: a : u$. (See *figure, theorem* 7.)

Or, if the subtangent $PT = s$, then will $CT = CP - PT = x - s$. Whence $(x - s)x = a^2$ or $x^2 - sx = a^2$; expressed as in the same proposition of the ellipse.

### HYPERBOLA.—THEOREM 9.

319. If there be any tangent, and four perpendiculars to the line of axis, contained between the tangent and the line of axis, the rectangle under two, which passes through the vertices, will be equal to the rectangle of the third, which passes through the centre, and the fourth which is the ordinate.

# GEOMETRY.

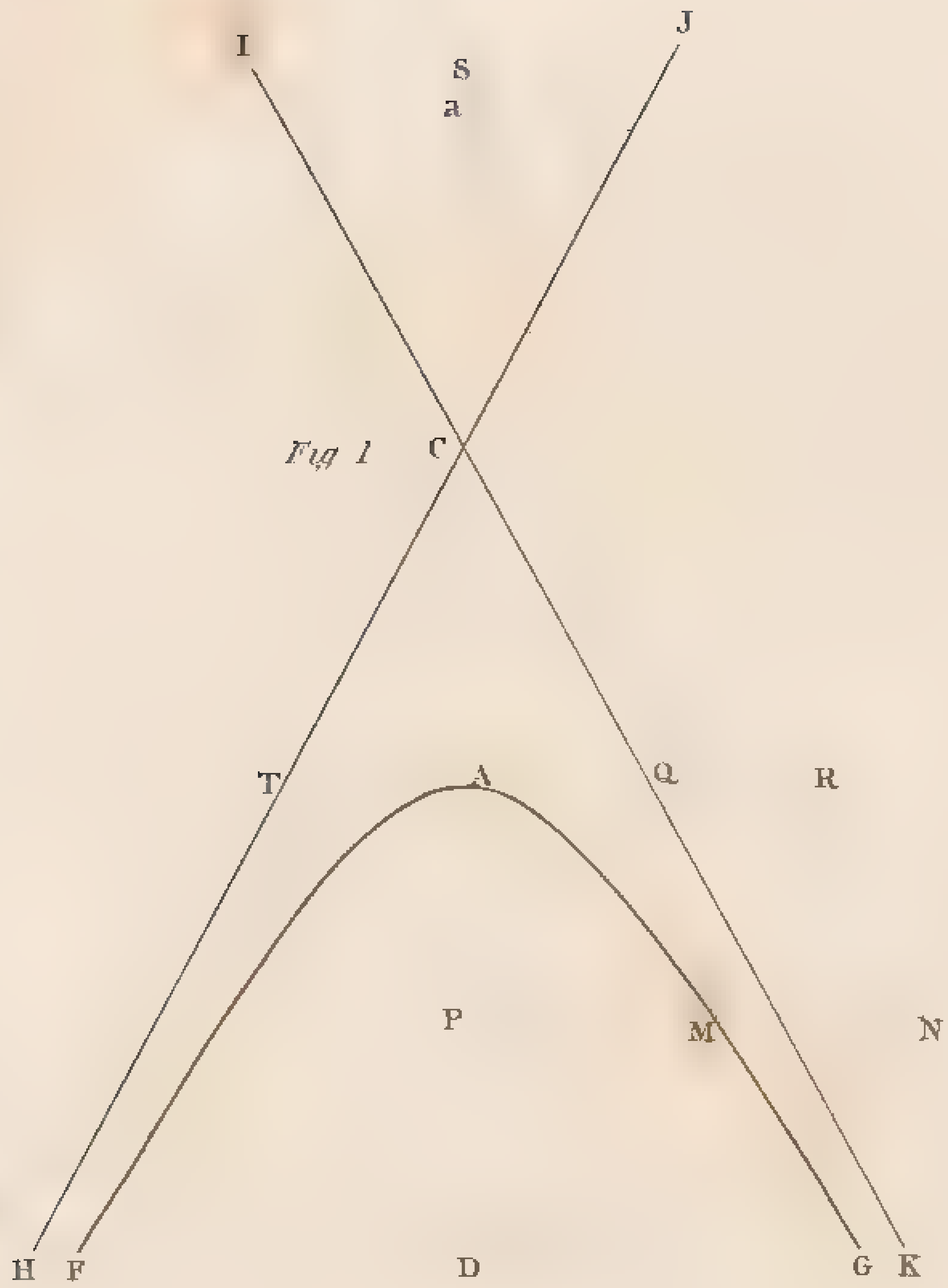



Fig 1

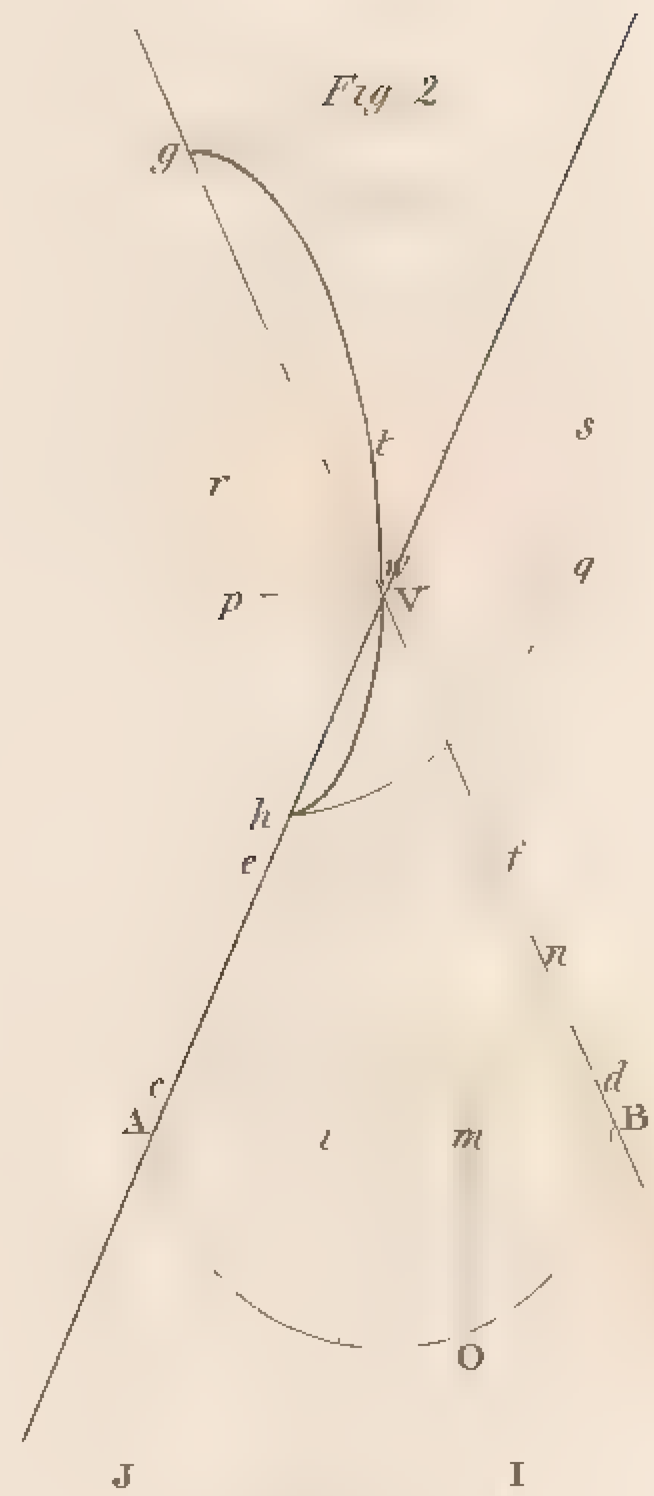



Fig 2

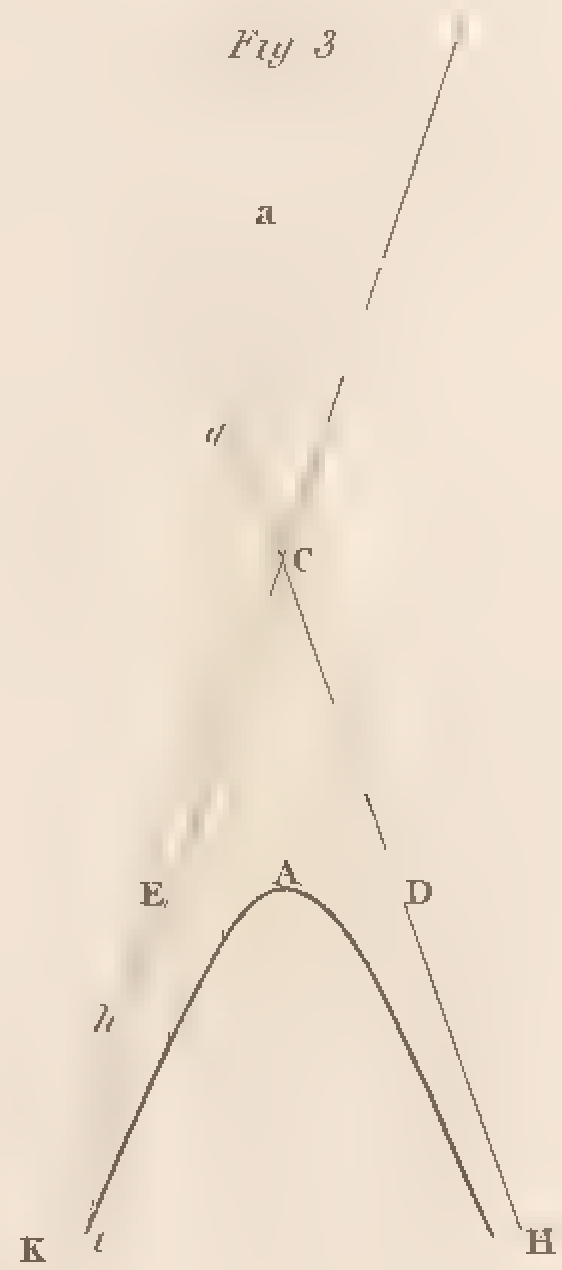



Fig 3

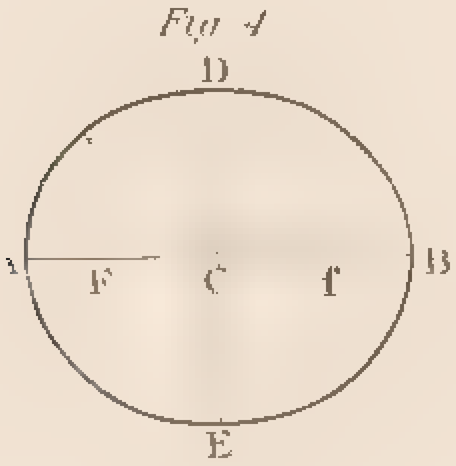



Fig 4

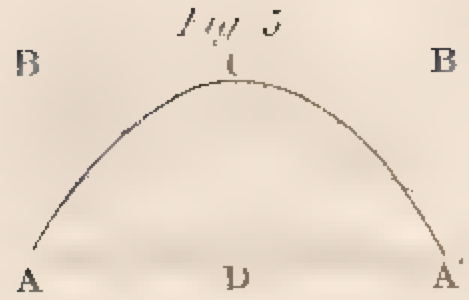
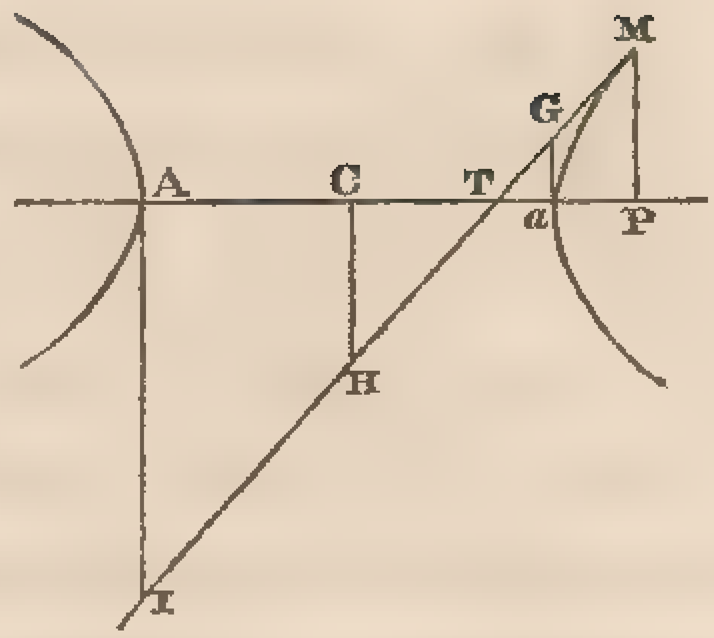



Fig 5

London Published by Thos. Kelly 17 Paternoster Row, January 1 1824.

Engraved by W. Symns




$$aG \times AI = CH \times PM$$

$$\text{or } aG : PM :: CH : AI.$$

PT being $= s$. See the preceding theorem.

Then...... $aP = CP - CA = x - a$

$u = CT = CP - PT = x - s$

$AT = CA + CP - PT = a + x - s$

$aT = PT - aP = s - x + a.$

Now, by *theorem* 8, $a^2 = x(x-s) = x^2 - sx$. Therefore, by transposition, $a^2 + sx - x^2 = O$; add $sx - x^2$ to each side of this equation, and $a^2 - x^2 + 2sx - s^2 = sx - s^2$, or $a^2 - (x^2 - 2sx + s^2) = s(x - s)$; and, since the difference of two squares is equal to the rectangle of the sum and difference of their roots, $(a + x - s)(a - x + s) = s(x - s)$.

Whence ............................ $AT \times aT = PT \times CT$

And, by similar triangles, $\begin{cases} TCH, TAI \;.. \; CT \times AI = CH \times AT \\ TaG, TPM \;.. \; aG \times TP = aT \times PM. \end{cases}$

Therefore, eliminating AT, $a$T, PT, CT, by multiplying these equations and $aG \times AI = CH \times PM$.

### HYPERBOLA.—PROBLEM.

320. Given the transverse axis of an hyperbola and an ordinate, to find the conjugate axis and assymtotes, (which are two straight lines, such as, if produced indefinitely with the curve, will never meet each other,) and thence to describe the curve itself.

Let Aa, (*fig.* 1, *pl.* V,) be the transverse axis, and let PM be an ordinate. Make PD equal to AP. Then on aD describe the semi-circle aND. Produce PM to N. Draw AR perpendicular to CD, and make AR equal to CA. Join NR, and produce NR and DA, if necessary, to meet each other in S; and draw MS, cutting AR in Q. Produce QA to T, and make AT equal to AQ. Then QT will be the conjugate axis, or AQ, AT, will each be the semi-conjugate axis. Through the points C, T, draw JH; and through the points C, Q, draw IK: then JH and IK are the *assymtotes*, by which the curve may be described.

Because $CP = x$, and $CA = a$, $AP = PD = x - a$, and aP equal to $x + a$; therefore PN is a mean proportional between $x + a$ and $x - a$, or between aP and PD; but, in the hyperbola, the transverse axis is to the conjugate as the mean proportion between $x + a$, and $x - a$ to the ordinate $y$ or PM; but AR is divided in Q, in the same ratio as PN is in N. Therefore PN : PM :: AR : AQ. That is, as the mean proportional between $x + a$, and $x - a$ is to the ordinate PM, so is the semi-transverse axis to the semi-conjugate axis.

## OF THE PARABOLA.

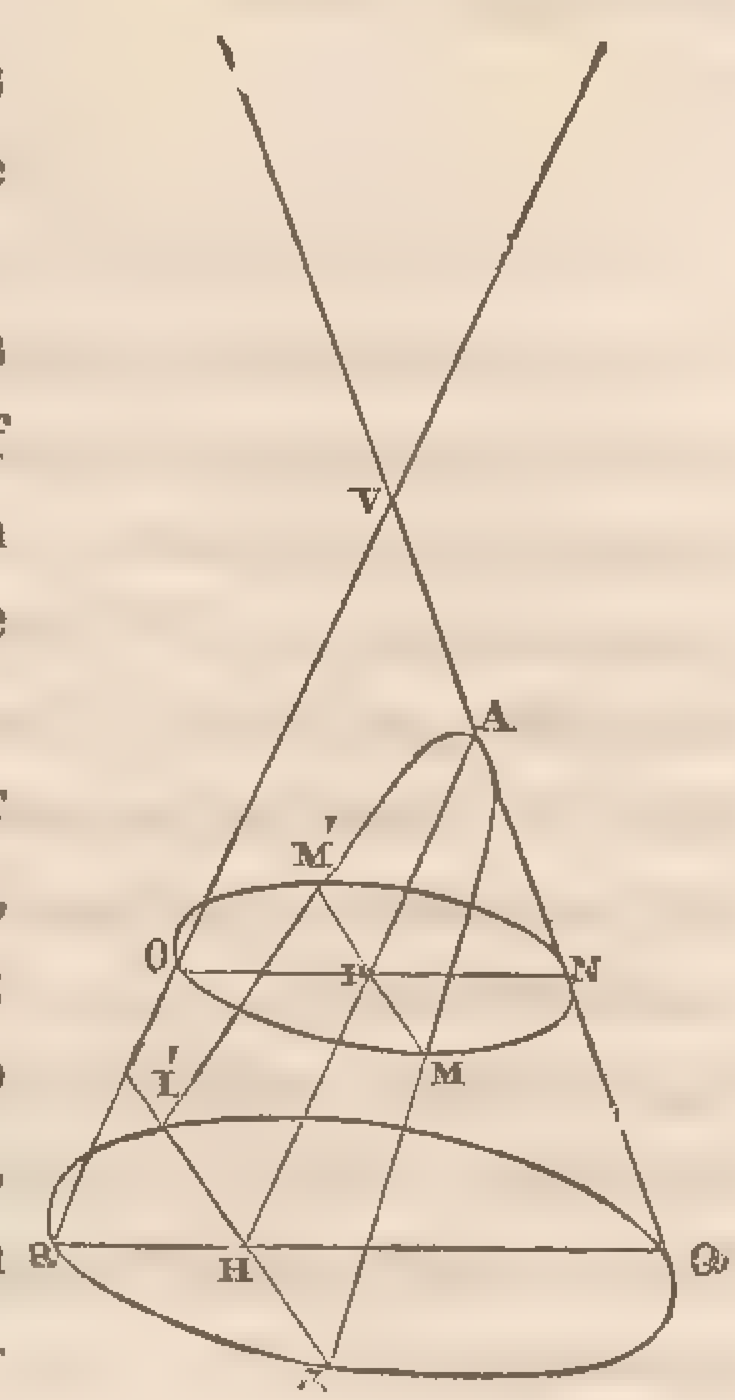
### DEFINITIONS RELATIVE TO THE PARABOLA.

321. That portion of the primary line which is within the curve, and which is terminated at one extremity by the vertex, is called the *axis.*

322. A straight line, drawn perpendicularly to the axis, between it and the curve, is called an *ordinate.*

### PARABOLA.—THEOREM 1.

323. The squares of the ordinates of the axis are to each other as their distances from the vertex.




Let VRQ be a plane, passing through the axis of the cone, perpendicular to the cutting plane of the section AMII′M′; and let AH be their common section; then AH will be the axis. Let QIRI′ be a section of the cone parallel to the base:

Then, because the base RIQI′ is perpendicular to the plane VRQ, the two sections AMII′M′, OMNM′, are perpendicular to the plane VRQ; therefore their common sections, MM′, II′, are also perpendicular to VRQ and to the lines AH, RQ, ON; but, because the plane VRQ passes through the axis of the cone, it will divide every circle pa-

rallel to the base into two equal parts; therefore ON is a diameter of the circle OMNM′; and, because the chords MM′, II′, are perpendicular to the diameters RQ, ON, they will be bisected; let H be the point of bisection in II′, and P the point of bisection in MM′.

324. Let AP$=x$, PM$=y$, AH$=z$, HI$=\gamma$, HQ$=v$, HR$=$OP$=w$, and PN$=t$.

By similar triangles, .. APN, AHQ...... $vz=tz$

and, by the circle, ......... QIR...... $\gamma^2=vw$

and, by the circle, ..........NMO......$tw=y^2$.

By multiplying these equations, the result will be $x\gamma^2=zy^2$. Therefore $x : z :: y^2 : \gamma^2$.

325. Corollary 1.—Hence $\frac{y^2}{x}=\frac{\gamma^2}{z}$.

326. Corollary 2.—Hence, because $\frac{y^2}{x}=\frac{\gamma^2}{z}$, whatever may be the values of $x, z, y, \gamma$, therefore $\frac{y^2}{x}$ or $\frac{\gamma^2}{z}$ is a constant quantity: hence, putting $\frac{y^2}{x}=\frac{1}{2}p$; therefore $y^2=\frac{1}{2}px$.

### PARABOLA.—DEFINITIONS, CONTINUED.

327. The constant quantity $p$ is called the *parameter* or *latus rectum.*

328. Corollary.—Hence the parameter is a third proportional to the distance of the ordinate from the vertex, and the ordinate itself; for $2x : 2y :: 2y : p$, or $px=2y^2$, that is, $y^2=\frac{1}{2}px$.

### THE THREE CURVES OF THE CONIC SECTIONS.—PROBLEM.

329. The vertical section of a right cone being given, and the position of the axis of a conic section, to describe that section.

Let AVB, (*fig.* 2, *pl.* V,) be the section of a cone through its axis; let *ig* be the line of the axis, and let it cut the section AVB at *h*, and the opposite side BV, produced, at *g*. On *gh* describe the semi-circle *hqsg*. Draw V*p* parallel to AB, cutting the axis in *p*. Bisect *hg* in *r*, and draw *pq*, *rs*, perpendicular to *hg*. Make *pw* equal to *p*V; then, with the transverse axis, *hg*, and the ordinate, *pw*, describe the ellipse *hwtg*, cutting *rs* at *t*; then *rt* is the semi-conjugate axis.

In *fig.* 3, *pl.* V, draw the line aA, for the transverse axis, equal to *gh*, *fig.* 5; and bisect Aa in C, the centre. Through A draw DE, perpendicular to Aa;

make AD and AE each equal to *rt*, *fig*. 2. Through C and D draw JH, and through C and E draw IK; then JH and IK are the assymtotes.

Draw any line, a*i*, cutting the assymtote IK at *h*, and the assymtote JH at *g*. Make *hi* equal to *ag*, and *i* will be a point in the curve. In the same manner we may find as many more points as we please.

Let the axis be *cf*, *fig*. 2, cutting the sides of the section AV, BV, at *c* and *f*. Draw *cd*, *ef*, parallel to AB, cutting AV at *e* and BV at *d*.

In *fig*. 4, draw AB equal to *cf*, *fig*. 2. Bisect AB in C. Make CF, C*f*, each equal to the half of *df*, or the half of *ce*; then, with the transverse axis AB, and focii F, *f*, describe the ellipse ADBE.

Again, in *fig*. 2, let the axis be *mn*, and let *mn* be parallel to the side AV of the vertical section, cutting the base AB at *m*, and the side BV at *n*. On AB describe the semi-circle AOB, and draw *m*O perpendicular to AB.

In the straight line AA′, *fig*. 5, take any point, D, and make DA, DA′ each equal to *m*O, *fig*. 2. Draw DC, perpendicular to AA′, and make DC equal to *mn*, *fig*. 2. Then, with the abscissa AB, and ordinates DA, DA′, describe the curve ACA′, which will be the parabola.

# CHAPTER II.

## CARPENTRY.

Carpentry is the art of applying timber in the construction of buildings.

The cutting of the timbers, and adapting them to their various situations, so that one of the sides of every timber may be arranged according to some given surface, as indicated in the designs of the architect, requires profound skill in geometrical construction.

For this purpose it is necessary, not only to be expert in the common problems, generally given in a course of practical geometry, but to have a thorough knowledge of the sections of solids and their coverings. Of these subjects, the first has already been explained in the series of Problems given in the geometrical part of this Work, and we are now about to treat on the other; that is, the Method of Covering them.

As no line can be formed on the edge of a single piece of timber, so as to arrange with a given surface, nor in the intersection of two surfaces, (by workmen called a *groin,*) without a complete understanding of both, the reader is required not to pass them until the operations are perfectly familiar to his mind. For the more effectually rivetting the principles upon the mind of the student, it is requested that he should *model* them as he proceeds, and apply the sections and coverings found on the paper to the real sections and surfaces, by bending them around the solid.

The Surfaces, which timbers are required to form, are those of *cylinders, cylindroids, cones, cuneoids, spheres, ellipsoids,* &c., either entire, or as terminated by cylinders, cylindroids, cones, and cuneoids.

The FORMATION of ARCHES, GROINS, NICHES, ANGLE-BRACKETS, LUNETTES, ROOFS, &c. depend entirely upon their *Sections*, or upon their *Covering*, or upon both.

This branch of carpentry, from its being subjected to geometrical rules, and described in schemes or diagrams upon a floor, sufficiently large for all the parts of the operation, has been called DESCRIPTIVE CARPENTRY.

In order to prepare the reader's mind for this subject, it will be necessary to point out the figures of the sections, as taken in certain positions.

ALL THE SECTIONS OF A CYLINDER, parallel to its base, are *circles*. All the sections of a cylinder, parallel to its axis, are *parallelograms*. And, if the axis of the cylinder be perpendicular to its base, all these parallelograms will be *rectangles*. If a cylinder be entirely cut through the curved surface, and if the section is not a circle, it is an *ellipse*.

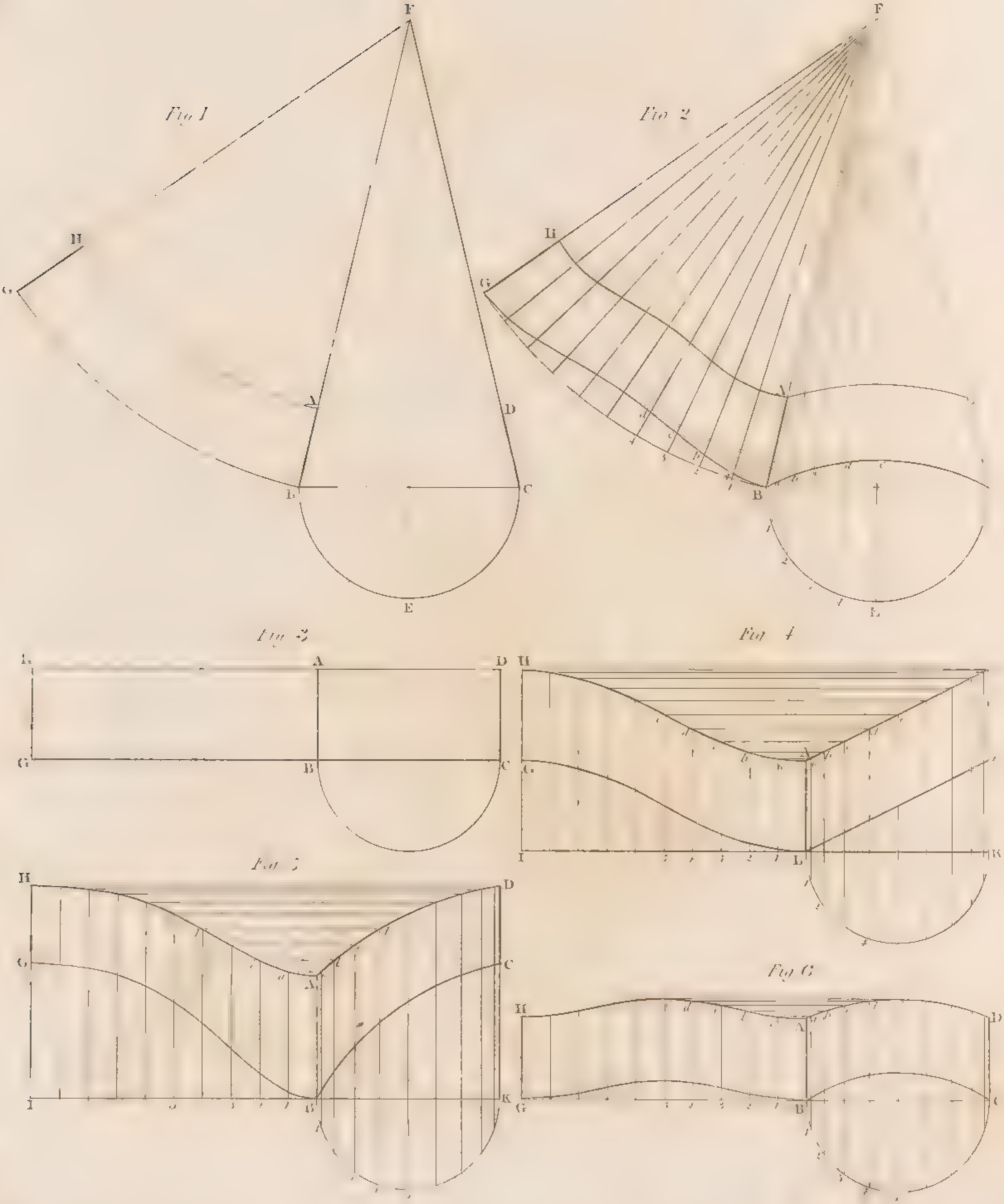
ALL THE SECTIONS OF A CONE, parallel to its base, are *circles:* all the sections of a cone, passing through its vertex, are *triangles:* all the sections of a cone, which pass entirely through the curved surface, and which are not circles, are *ellipses* : all the sections of a cone, which are parallel to one of its sides, are denominated *parabolas;* and all the sections of a cone, which are parallel to any line within the solid, passing through the vertex, are denominated *hyperbolas*.

ALL THE SECTIONS OF A SPHERE OR GLOBE, made plane, are *circles*.

The solid formed by a SEMI-ELLIPSE, revolving upon one of its axes, is termed an *ellipsoid*.

ALL THE SECTIONS OF AN ELLIPSOID are similar figures: those sections, perpendicular to the fixed axis, are circles; and those parallel thereto are similar to the generating figure

# COVERINGS OF SOLIDS.



## OF THE COVERINGS OF SOLIDS.

### PROBLEM 1.

To find the covering of the frustum of a right cone.

Let ABCD (*fig.* 1, *pl.* VII,) be the generating section of the frustum. On BC describe the semi-circle BEC, and produce the sides BA and CD, of the generating section ABCD, to meet each other in F. From the centre F, with the radius FA, describe the arc AH; and, from the same centre, F, with the radius FB, describe the arc BG; divide the arc, BEC, of the semi-circle, into any number of equal parts; the more, the greater truth will result from the operation; repeat the chord of one of these equal arcs upon the arc BG, as often as the arc BEC contains equal parts; then, through G, the extremity of the last part, draw GF, cutting the arc AH at H; then will ABGH be the covering required.

### PROBLEM 2.

To find the covering of the frustum of a right cone, when cut by two concentric cylindric surfaces, perpendicular to the generating section.

Let ABCD (*fig.* 2, *pl.* VII,) be the given section, and AD, BC, the line on which the cylindric surface stands. Find the arc BG, as before, in *problem* 1, and mark the points, 1, 2, 3, &c. of division, both in the arc BG, and in the semi-circumference; from the points 1, 2, 3, &c. draw lines to F; also from the points 1, 2, 3, &c. in the semi-circumference, draw lines perpendicular to BC; so that each line thus drawn may meet or cut it. From the points of division in BC, draw more lines to F, cutting the arc BC in *a, b, c,* &c. From the points *a, b, c,* &c. draw lines parallel to BC, to cut the side BA: from the centre F, through each point of section in BA, describe an arc, cutting the lines drawn from each of the points 1, 2, 3, &c., in BG, at *a, b, c,* &c.; then will B*e*G be the curve, which will cover the line BC on the plan, or BC will be the seat of the line B*e*G.

In the same manner AH, the original of the line AD, will be found; and, consequently, B*e*GHA will form the covering over the given seat, ABCD, as required to be done.

### PROBLEM 3.

To find the covering of a right cylinder.

Let ABCD (*fig.* 3, *pl.* VII,) be the seat or generating section. Produce the sides DA and CB to H and G, and on BC describe a semi-circle, and make the straight line BG equal to the semi-circumference: draw GH parallel to AB, and AH parallel to BG; then will ABGH be the covering required.

### PROBLEM 4.

To find the covering of a right cylinder contained between two parallel planes, perpendicular to the generating section (*fig.* 4, *pl.* VII).

Through the point B draw IK, perpendicular to AB, and produce DC to K; on BK describe a semi-circle, and make BI equal to the length of the arc of the semi-circle, by dividing it into equal parts, and extending them on the line BI. Through the points of section, 1, 2, 3, &c., in the line BI, draw lines, 1*a*, 2*b*, 3*c*, &c., parallel to BA, and through the points 1, 2, 3, &c., in the arc of the semi-circle, draw the other lines 1*a*, 2*b*, 3*c*, &c., parallel to BA, cutting AD in *a*, *b*, *c*, &c. Draw *aa*, *bb*, *cc*, &c., parallel to BK; then, through the points, *a*, *b*, *c*, &c., draw the curve AH, and AH will be the edge of the covering over AD.

In the same manner the other opposite edge BG will be found, and the whole covering will therefore be ABGH.

### PROBLEM 5.

ABCD (*fig.* 5, *pl.* VII,) being the seat of the covering of a semi-cylindric surface, contained between the surfaces of two other concentric cylinders, of which the axis is perpendicular to the given seat; it is required to find the covering.

Through B draw IK, perpendicular to AB; and produce DC to K. On BK describe a semi-circle, and divide its circumference into equal parts, at the points 1, 2, 3, &c.; the more of these the truer will be the operation; and repeat the chord on the straight line BI, as often as the arc contains equal parts, and mark the points 1, 2, 3, &c., of division. Through the points

1, 2, 3, &c., in the arc of the semi-circle, draw the lines 1*a*, 2*b*, 3*c*, &c., parallel to BA; and, through the points 1, 2, 3, &c., in BI, draw lines 1*a*, 2*b*, 3*c*, &c., parallel to BA. Draw *aa*, *bb*, *cc*, &c., parallel to KI, and through all the points *a*, *b*, *c*, &c., draw the curve line AH, which is one of the edges of the covering.

In the same manner the other edge BG will be found; and, consequently, the whole covering ABGH.

PROBLEM 6.

To find the covering of that portion of a semi-cylinder contained between two concentric surfaces of two other cylinders, the axis of these cylinders being perpendicular to ABCD (*fig.* 6, *pl.* VII).

Join BC, and, in this case, BC will be perpendicular to AB. Produce CB to G; and, on BC, describe a semi-circle. Divide the arc of the semi-circle into any number of equal parts, and extend the chords upon the straight line BG, marking the points of section both in the semi-circle and in the straight line BG. Through the points, 1, 2, 3, &c., in the arc of the semi-circle, draw lines 1*a*, 2*b*, 3*c*, &c., parallel to AB; and through the points 1, 2, 3, &c., in BG, draw the lines 1*a*′, 2*b*′, 3*c*′, &c., parallel to AB; also draw *aa*′, *bb*′, *cc*′, &c., parallel to BG, and, through the points *a*, *b*, *c*, &c, draw a curve, which will form one of the edges of the soffet; the opposite edge is formed in the same manner.

## GROINS AND ARCHES.

Groins are the intersections of the surfaces of two arches crossing each other.

### CONSTRUCTION OF GROINED ARCHES.

Groined Arches may be either formed of wood, and lathed over for plaster, or be constructed of brick or stone.

When constructed of brick or stone, they require to be supported upon wooden frames, boarded over, so as to form the convex surface, which each

vault is required to have, in order to sustain the cross arches during the time of turning them. This construction is called a CENTRE, and is removed when the work is finished. The framing consists of equidistant ribs, fixed in parallel planes, perpendicular to the axis of each body; so that, when the under sides of the boards are laid on the upper edges of the ribs, and fixed, the upper sides of the boards will form the surface required to build upon.

In the construction of the centering for groins, one portion of the centre must be completely formed to the surface of its corresponding vault, without any regard to the cross-arches, so that the upper sides of the boards will form a complete cylindric or cylindroidic surface. The ribs of the cross-vaults are then set at the same equal distances as that now described; and parts of ribs are fixed on the top of the boarding at the same distances, and boarded in, so as to intersect the other, and form the entire surface of the groin required.

Groins constructed of wood, in place of brick or stone, and lathed under the ribs, and the lath covered with plaster, are called *plaster-groins*.

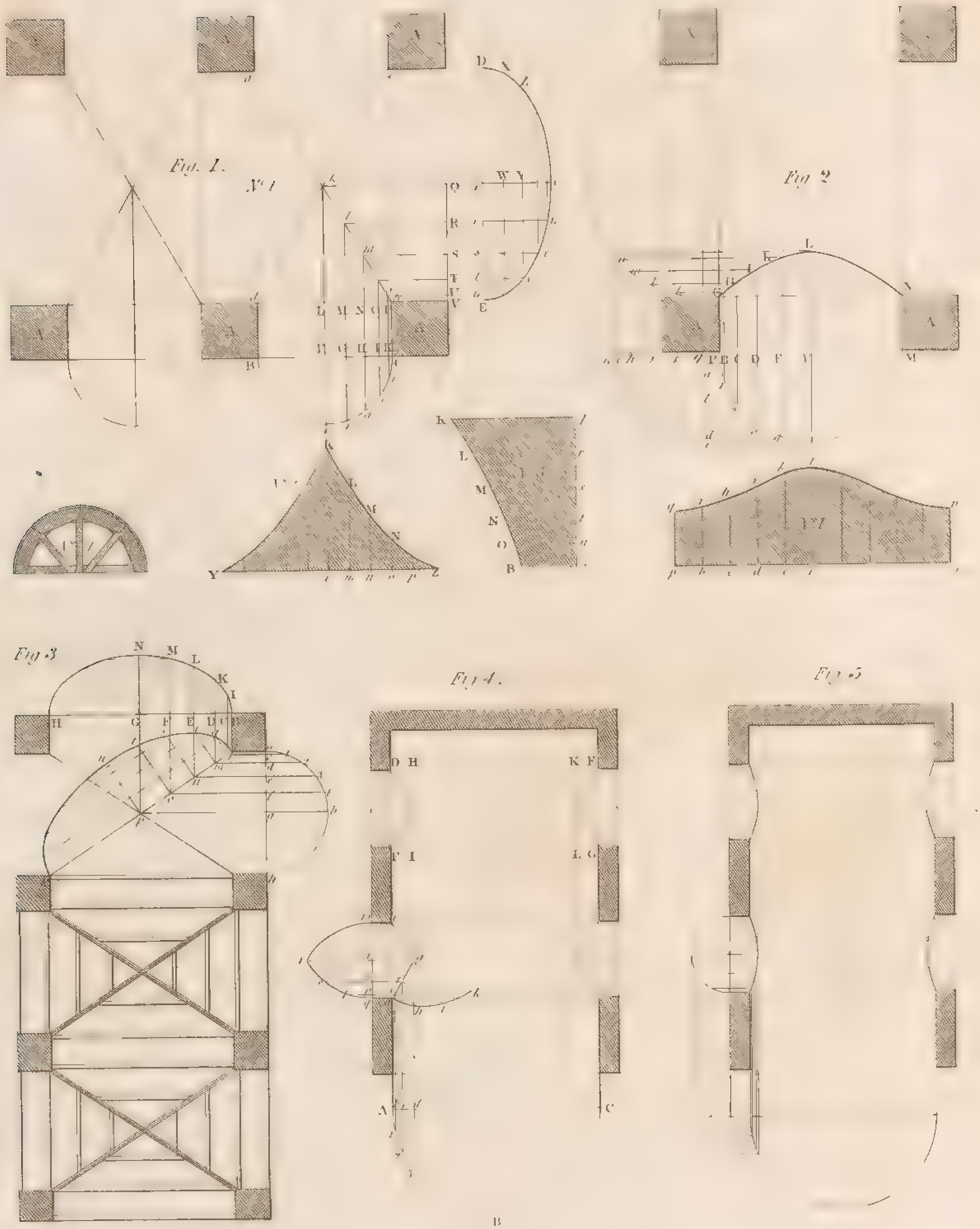
PLASTER-GROINS are always constructed with diagonal ribs intersecting each other, then other ribs are fixed perpendicular to each axis, in vertical planes, at equal distances, with short portions of ribs upon the diagonal ribs; so that, when lathed over, the lath may be equally stiff to sustain the plaster.

When the axis and the surface of a semi-cylinder cuts those of another of greater diameter, the hollow surface of the lesser cylinder, as terminated by the greater cylinder, is called a *cylindro-cylindric arch*, and, vulgarly, a *Welsh groin*.

CYLINDRO-CYLINDRIC ARCHES, or *Welsh groins*, are constructed either of brick, stone, or wood. If constructed of brick or stone, they require to have centres, which are formed in the same manner as those for groins; and, if constructed of wood, lath, and plaster, the ribs must be formed to the surfaces.

In the construction of groins, and of cylindro-cylindric arches, the ribs that are shorter than the whole width are termed *jack-ribs*.

# GROINS AND ARCHES.




Drawn by P. Nicholson

London, Published by Thos. Kelly, 17 Paternoster Row January 1, 1822.

Engraved by W. Symns

Cellars are frequently groined with brick or stone, and sometimes all the rooms of the basement stories of buildings, in order to render their superstructures proof against fire. The surfaces of brick or stone, on which the first arch stones, or course of bricks, are placed, are called the *springing of the arches*. It is evident that the more weight that is put on the side-walls, which sustain arches, the more will they be able to sustain the pressure of the arches; therefore the higher a wall is, the greater the weight will be on each of the side-walls; and for this reason groins are often constructed of wood in upper stories, instead of brick or stone, as not being liable to thrust out the walls, or bulge them, by the lateral pressure of the arches. The upper stories of buildings are never groined with stone or brick, unless when the walls are sufficiently thick to sustain the lateral pressure of the arches. The ceilings of Gothic buildings were frequently constructed with groined arches of stone, which were obliged to be supported with buttresses, at the springing points of the arches.

### GROINS AND ARCHES.—PROBLEM 1. (*fig.* 1, *pl.* VIII.)

Given the plan of a rectangular groined arch or vault, of which the openings are of different widths, but of the same height, and a section of one of the arches, as also the seats of the groins, to find the covering of both arches, so as to meet their intersection.

In *fig.* 1, *pl.* VIII, let A, A, A, &c., be the plan of the piers, and *ab*, *cd*, the seats of the groins.*

Let the section of the arch, standing upon the lesser opening, BC, be a semi-circle: it is required to find the section upon the greater opening and the ends of the boards, so as to meet the groin, or line of intersection, of the two surfaces.

* The difference between the *plan* of any body and the *seat* of a point or line is distinguished thus: The *plan* is a figure upon which a solid is carried up, so that all sections, parallel to the plan, are equal and similar to that plan, and the surfaces are perpendicular; but the *seat* of a line is not in contact with the line itself; but a perpendicular erected from any point in the seat will pass through its corresponding point of the line itself.

On the diameter BC describe a semi-circle, and divide the quadrant into any number of equal parts, *ef*, *fg*, *gh*, &c., and from the points *e*, *f*, *g*, &c., draw lines, parallel to the axis F*k*, to meet the seat *ab* of the groined line, or line of intersection of the two surfaces. From the points *k*, *l*, *m*, &c. of intersection, draw the lines *k*Q, *l*R, *m*S, &c., parallel to the axis of the other vault, to meet the line VQ, perpendicular to that other axis in the points Q, R, S, &c. Then, upon any line, DE, transfer the points Q, R, S, &c. to *q*, *r*, *s*, &c., and draw *qv*, *rw*, *sx*, &c. perpendicular to DE, and transfer the ordinates F*e*, G*f*, H*g*, &c., of the semi-circle, to *qv*, *rw*, *sx*, &c., and through the points *v*, *w*, *x*, &c. draw a curve; then *qv*E will be half of the section required.

To find the covering of the semi-cylinder. Upon any straight line, YZ, No. 2, set off the distances *lm*, *mn*, *no*, &c., each equal to the chord *ef* or *fg*, &c., in No. 1; and draw *l*K, *m*L, *n*M, &c., in No. 2, perpendicular to YZ. Make *l*K, *m*L, *n*M, &c., No. 2, equal to L*k*, M*l*, N*m*, &c., of No. 1, and through the points K, L, M, &c., No. 2, draw a curve. Then will the figure K*l*Z be half of the covering of the cylinder.

To construct the covering, No. 3, for the great opening.

In the straight line *vq*, No. 3, make *vu*, *ut*, *ts*, &c., equal to the parts, E*z*, *zy*, *yx*, &c., of the elliptic curve, No. 1. In No. 3, draw *v*B, *u*O, *t*N, *s*M, &c., and make *v*B, *u*O, *t*N, *s*M, &c., No. 3, equal V*b*, U*o*, T*n*, S*m*, &c., No. 1; and in No. 3, draw a curve through the points B, O, N, M, &c.; then *qv*BK*q* will be the covering required.

### GROINS AND ARCHES.—PROBLEM 2. (*fig.* 2, *pl.* VIII.)

To find the groin of a cylindro-cylindric arch.

Let A, A, A, A, be the plans of four piers, which form the openings of different widths. On the lesser opening PM, as a diameter, describe a semicircle. Divide the quadrant next to P into any number of equal parts, and through the points of section draw the lines 1G, 2H, 3I, &c., perpendicular to PM, cutting PM in B, C, D, &c., and through the same points 1, 2, 3, &c., draw the lines 1*a*, 2*b*, 3*c*, &c., parallel to PM, cutting a line *qe* perpendicular to PM in the points *a*, *b*, *c*; produce the line which contains the points *a*, *b*, *c*,

through the greater opening; and upon the part of the line thus produced, which is intercepted between the piers A, A, describe a semi-circle. Produce the line MP to *k*, and from *q* describe arcs *af, bg, ch,* &c., cutting B*k* in the points *f, g, h,* &c. Draw *fk, gl, hm,* &c., parallel to the base of the greater semi-circle, to cut the arc of the same in the points, *k, l, m,* &c. From the points *k, l, m,* &c., draw the lines *k*G, *l*H, *m*I, &c., parallel to PM; then, through the points G, H, I, K, L, draw a curve GHIKL, which will be the seat of the groin.

The covering to coincide with the groin is shown at No. 1. Draw *pm,* No. 1, and make *pb, bc, cd,* &c., each equal to P1; 1, 2; 2, 3, &c., in the semi-circular arc. In No. 1, draw *pq, bg, ch,* &c., respectively equal to BG, CH, DI, &c., and through the points *q, g, h, i,* &c., draw a curve; then will *pqnm* be the covering required.

### GROINS AND ARCHES.—PROBLEM 3. (*fig.* 3, *pl.* VIII.)

To find the diagonal or groin-rib of a Vault, of which the lesser openings are semi-circles, and the groins, in vertical planes, passing through the diagonals of the piers.

On *ah,* (*fig.* 3, *pl.* VIII,) the perpendicular distance between two adjacent piers of the lesser opening, describe a semi-circle, *abh*; and, in the arc, take 1, 2, 3, &c., any number of points, and draw the lines 1*l*, 2*m*, 3*n*, &c., cutting the diagonal *ik,* in *l, m, n,* &c. Draw, as before, *lq, mr, ns,* &c., perpendicular to *ik,* and through the points *i, q, r, s,* &c. draw a curve; then *iuk* will be the edge of the rib to be placed in the groin.

The edge of the rib, for the other opening, will be found thus: From the points *l, m, n,* &c., draw the lines, *l*I, *m*K, *n*L, &c., parallel to the axis of the opening of the larger body, cutting HB at the points C, D, E, &c. Make CI DK, EL, &c., each equal to *c*1, *d*2, *e*3, &c.; then, through the points B, I, K, L, &c., draw a curve; and the line thus drawn will be in the surface of the greater opening, so that BNH will be one of the ribs of the body-range.

The method of placing the ribs is exhibited at the lower end of the diagram, *fig.* 3, the ribs of each opening being placed perpendicular to the axis of each groin.

### GROINS AND ARCHES.—PROBLEM 4. (*fig.* 4, *pl.* VIII.)

To find the groined and side ribs of a LUNETTE, where the groined ribs are in vertical planes upon the straight lines *ag*, *gl*, (*fig.* 4, *pl.* VIII,) the principal arch being a semi-circle.

Let AC be the base of one of the principal arches, perpendicular to one of the sides of the main vault, the points A and C being in the same range with those sides. Let *mq* be the opening of one of the lunette windows. From the point *g*, the meeting of the two seats of each groin, draw *gr* perpendicular to *mq*, cutting *mq* at *n*; draw *g*3 parallel to *mq*, cutting the semi-circular arc ABC at 3. Between A and 3 take any number of intermediate points, 1, 2, &c., and, through the points 1, 2, &c., thus assumed, draw 1*e*, 2*f*, &c., cutting the seat *ag*, of the first groin, in the points *e*, *f*, &c., and AC in *b*, *c*, *d*, &c. Perpendicular to *ag* draw *eh*, *fi*, &c., and make *eh*, *fi*, *gk*, each equal to *b*1, *c*2, *d*3, &c.; then, through the points *g*, *h*, *i*, *k*, draw a curve, which will form the groin belonging to the seat *ag*. From the points *e*, *f*, &c., draw lines *et*, *fs*, &c., cutting *qm* in the points *p*, *o*, &c.; and, through the points *q*, *t*, *s*, *r*, draw the curve *qtsr*, which will be one of the ribs of the lunette.

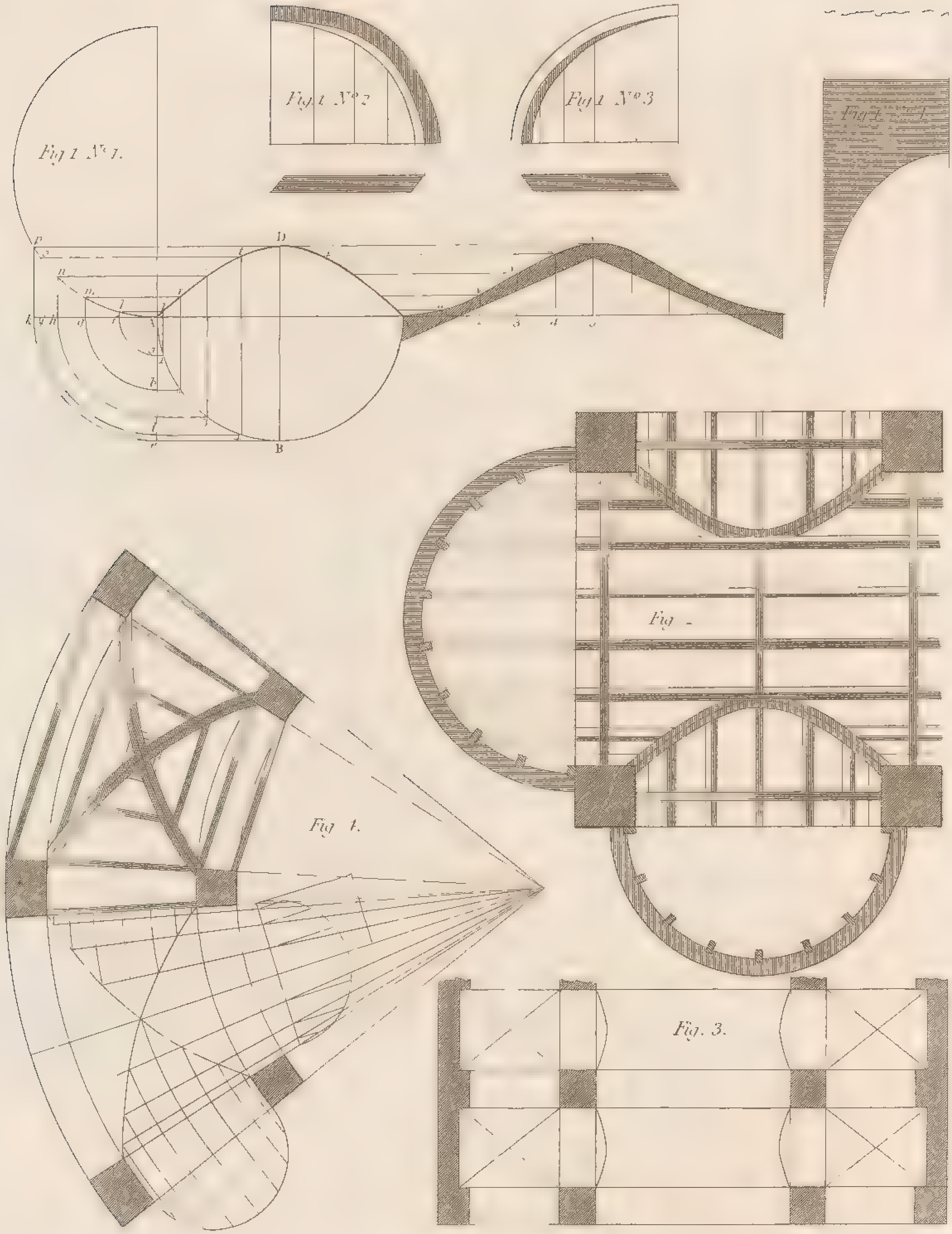
### GROINS AND ARCHES.—PROBLEM 5. (*fig.* 5, *pl.* VIII.)

Given one of the ribs of a LUNETTE, and a rib of the main arch, to determine the seat of the groin, or the seat of the intersection of the two surfaces.

This is, in fact, a cylindro-cylindric arch; we shall therefore refer the reader to *Problem* 2, for the geometrical construction of the same.

LUNETTES are used in large rooms or halls, and are made either in waggon-headed ceilings, or through large coves, surrounding a plane ceiling: they have a very elegant effect when they are numerous, and disposed at equal distances. Though it is not necessary to have the axes of the lunettes and the axes of the quadrantal cylindric surfaces in the same plane, they have the best effect when executed so; as the groin, formed by the meeting of the two surfaces, has, in this case, less projection: and, though the groins are curves of double curvature, their seats are perfect hyperbolas, and may be

# GROINS AND ARCHES.




*Drawn by P. Nicholson.*

*Engraved by [illegible]*

*London, Published by Thos. Kelly, 17, Paternoster Row, Jany. 1, 1822.*

described independent of the rules of projection, the summit or vertex of the curve being once ascertained: by these means we shall have the abscissa and double ordinate; the transverse axis being the distance between the opposite curves.

GROINS AND ARCHES.—PROBLEM 6. (*fig.* 1, *pl.* IX.)

To find the groin of a CYLINDRO-CYLINDRIC ARCH, and the moulds for the boarding.

*A Cylindro-cylindric Arch* is the intersection of one semi-cylinder, of a less diameter, with another of a greater diameter. The principal objects to be found are, the seat of the curve on the plan, and the moulds for terminating the ends of the boards.

For this purpose, on any straight line, which has A at one of its ends, as a diameter, describe a semi-circle, as at No. 1, in the figure, terminating in A, for the section of the greater vault, or semi-cylindric arch. As the axis of the one cylinder is supposed to cut the axis of the other at right angles, the sides of the cross-vaults will also be at right angles to each other: therefore draw the diameter AC, of the lesser vault, perpendicular to the diameter of the greater vault; and on AC, as a diameter, describe the semi-circle ABC: divide the quadrantal arc AB into any number of equal parts, as here into five. Draw A*e* perpendicular to AC, and produce CA to *k*. Through the points of division, in the quadrantal arc AB, draw 1*a*, 2*b*, 3*c*, 4*d*, B*e*, cutting A*e*, in *a*, *b*, *c*, *d*, *e*. Again, through the same points 1, 2, 3, 4, B, in the quadrantal arc AB, draw straight lines 1*q*, 2*r*, 3*s*, 4*t*, BD, perpendicular to AC. From the point A, as a centre, with the several distances A*a*, A*b*, A*c*, A*d*, A*e*, describe the arcs *ek*, *di*, *ch*, *bg*, *af*, cutting A*k* in *f*, *g*, *h*, *i*, *k*.

Parallel to the diameter of the greater semi-circle, or parallel to A*e*, (*fig.* 1, No. 1,) draw *fl*, *gm*, *hn*, *io*, *kp*, cutting the greater semi-circular arc in the points *l*, *m*, *n*, *o*, *p*. Through the points *l*, *m*, *n*, *o*, *p*, draw *lq*, *mr*, *ns*, *ot*, *p*D, parallel to AC, cutting the perpendiculars 1*q*, 2*r*, 3*s*, 4*t*, BD, in the points *q*, *r*, *s*, *t*, D. Through the points A, *q*, *r*, *s*, *t*, D, trace a curve by hand, or put in nails at the points A, *q*, *r*, *s*, *t*, D, and bend a thin slip of wood so as to come in

contact with all the nails; then, by the edge of this slip, which touches the nails, draw a line with a pencil, or find points; and the curve thus drawn will be half the seat of the rib. The other half, being exactly the reverse, may be found by placing the distances of the ordinates at the same distance from the centre, upon the diameter AC, and setting up the perpendiculars by making them respectively equal to the others.

It will perhaps be eligible to make the whole curve ADC at once.

The mould for cutting the ends of the boards, which are to cover the centres of the lesser openings, will be found as follows:

On any straight line, C5, as on the diameter AC produced, set off the equal parts A1; 2,3; 3,4; 4B; of the quadrant AB, on the straight line C5, from C to 1, from 1 to 2, from 2 to 3, from 3 to 4, from 4 to 5, and draw the straight lines 1*u*, 2*v*, 3*w*, 4*x*, 5*y*, perpendicular to C5. Make 1*u*, 2*v*, 3*w*, 4*x*, 5*y*, each respectively equal to each of the ordinates comprehended between the base AC, and the seat AD; then, through all the points C, *u*, *v*, *w*, *x*, *y*, draw a curve C*uvwxy*, as before; then the shadowed part, of which the curve line C*uvwxy* is the edge, is the *mould* for one side, which may also be made use of for the other.

To apply this mould, all the boards should be laid together, edge to edge, on a flat or plane surface, to the breadth C5. Draw a straight line C5, perpendicular to the edge of the first board, at the distance of 5*y* from the end. At the distance C5 draw a perpendicular 5*y*, and set off the distance 5*y*. Then apply the proper edge of the mould from C to *y*, as exhibited in the plate, and draw a curve across the boards, and cut their ends off by the line thus drawn; then the ends, thus formed of the remaining parts, will fit upon the boarding of the greater vault, after being properly bevelled, so as to fit upon the surface of the said boarding.

No. 4, of *fig*. 1, exhibits the curve, in order to draw or discover the line on the boarding of the greater vault, in order to place the boarding of the lesser vault.

Nos. 2 and 3, *fig*. 1, show the method of forming the inner edges of the ribs, so as to range with the small opening. The under edge of the rib must be

formed so as to correspond to the curve which is its seat; and the little distances, between the straight line and the curve, must be set off on the short lines, shown at Nos. 1, 2, and 3; then a curve may be drawn through the points of extension, and the superfluous wood taken away; then, the rib being put in its real place, the angle will exactly fall over its seat. The diagram, *figure* 1, and its different numbers, answer both the purposes of a centering and of ribbing for plaster-ceilings.

*Figure* 2, *pl.* IX, exhibits the method of forming the *Cradelling*, or ribs, for plaster-ceilings of cylindro-cylindric arches. Here principal ribs only are used across the piers. The ribs of double curvature, which form the groins, though here exhibited, in order to fix the ribs, may be done without, by men of experience: but young workmen require every assistance, in order to acquire a comprehensive idea of the subject; it is, therefore, proper to show how the groined ribs are to be found. The other ribs, for lathing upon, are made of straight pieces of quartering, fixed equidistantly.

*Figure* 3, *pl.* IX, is a plan in which common groins and cylindro-cylindric arches both occur. See the gate-way leading from the Strand, in London, into the court of Somerset-house.

### GROINS AND ARCHES.—PROBLEM 7. (*fig.* 4, *pl.* IX.)

To find the seats of the intersections of groins formed by the intersection of an annular and a radial vault, both being at the same height, the section of the annular vault being a semi-circle, and that of the radiating vault a semi-circle of the same dimensions, the plan being given.

Perpendicular to the middle line, or axis, of the radial vault, draw a straight line from any point of that middle line; from the point thus drawn, set the radius of the circle of the annular vault; from the point of extension draw a line, parallel to the axis of the radiating vault, to meet the side of the plan. From the point of meeting draw a straight line, perpendicular to the axis, to meet the other side of the plan of that radiating vault: on the perpendicular thus drawn, between the two sides, as a diameter, describe a semi-circle: divide each quadrantal arc of this semi-circle, and each quadrantal arc of the

semi-circle which is the section of the annular vault, into the same number of equal parts. Draw lines through the points of division in each arc, perpendicular to the base or diameter, to meet the said diameter. Through the points of section in the diameter of the annular vault, and from the point of concourse of the two sides of the radiating vault, describe arcs. From the same point of concourse, and through the points of section of the diameter of the semi-circle, which is the section of the radiating vault, draw lines from the point of concourse of the two sides of the radiating vault. Then, through the intersection of these lines, and the arcs drawn from the points of section in the diameter of the semi-circle, which is the section of the annular vault, trace a curve, which will be the seat of the groin. The method of fixing the timber is exhibited at the other end of the figure. The ribs of both the annular vault and the radiating vault are all fixed in right sections of these vaults, as must appear evident from what has been shown.

## NAKED FLOORING.

FLOORS are those partitions in houses that divide one story from another.

FLOORS are executed in various ways: some are supported by single pieces of timber, upon which boards for walking upon are nailed. Floors of this simple construction are called *single-joisted floors*, or *single floors;* the pieces of timber, which support the boards, being called *joists.* It is, however, customary to call every piece of timber, under the boarding of a floor, used either for supporting the boards or ceiling, by the name of *joists,* excepting large beams of timber into which the smaller timbers are framed.

When the supporting timbers of a floor are formed by one row laid upon another, the upper row are called *bridging joists,* and the lower row are called *binding joists.* Sometimes a row of timbers is fixed into the binding joists, either by mortises and tenons, or by placing them underneath, and nailing them up to the binding-joists: these timbers are called *ceiling-joists,* and are used for the purpose of lathing upon, in order to sustain the plaster-ceiling.

# NAKED FLOORING

## *AND LENGTHENING OF BEAMS.*

*Fig. 1.*

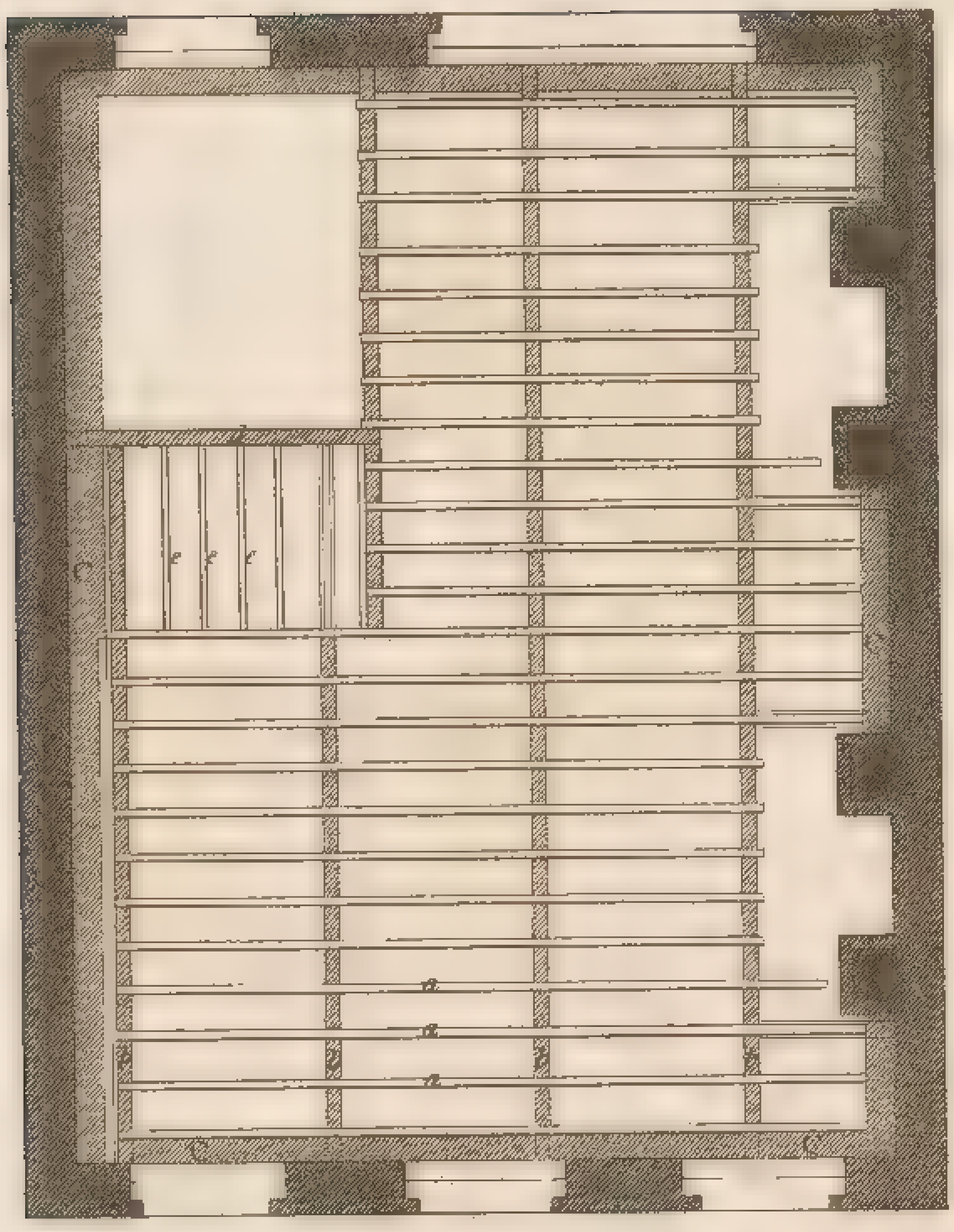


*Fig. 2.*

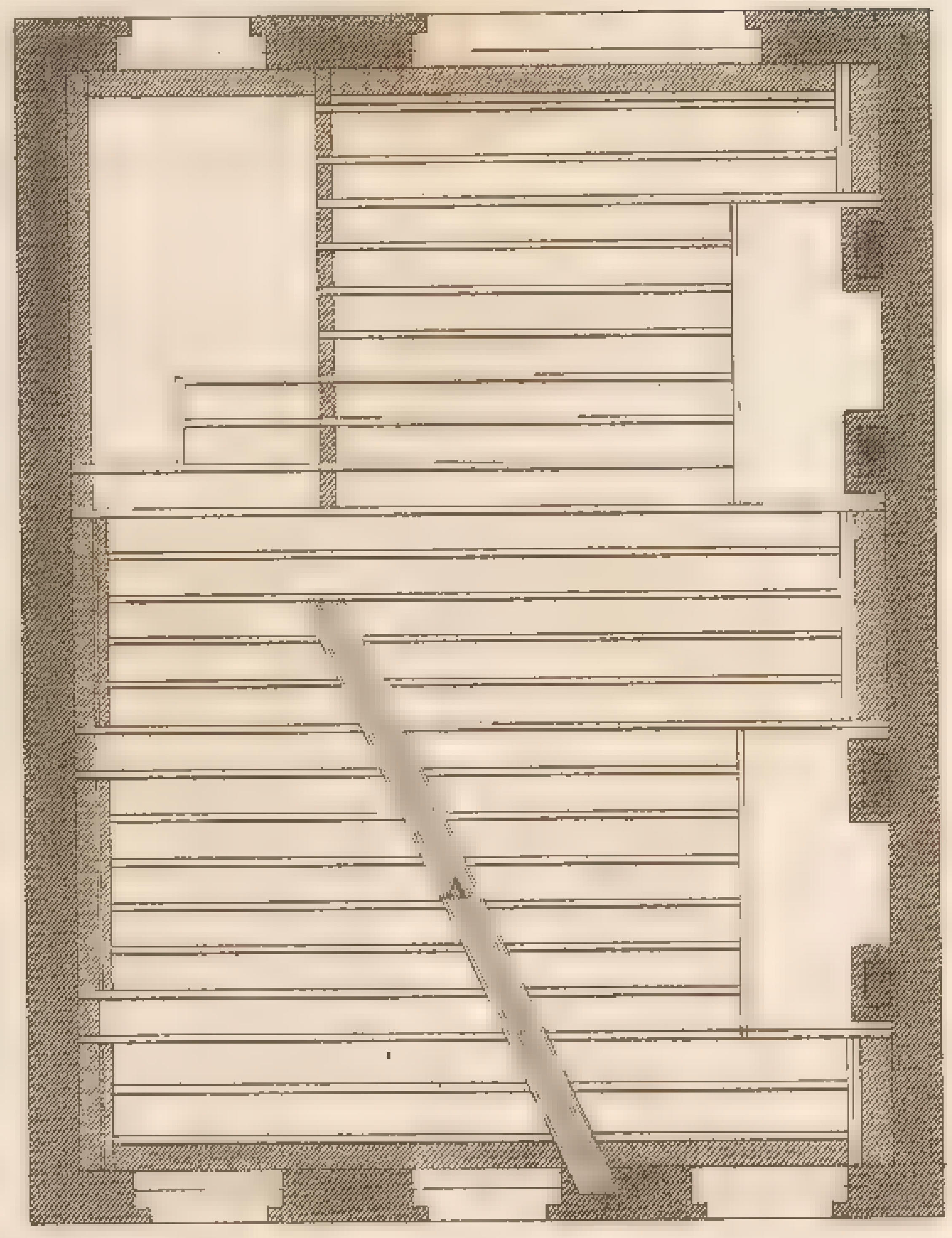


*Fig. 3*

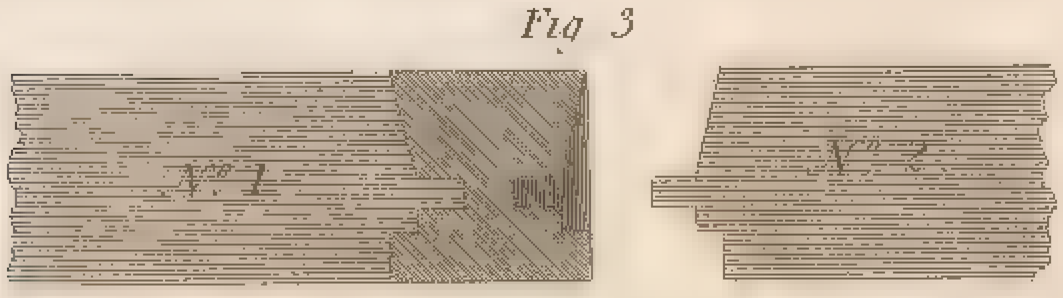



*Fig. 4.*

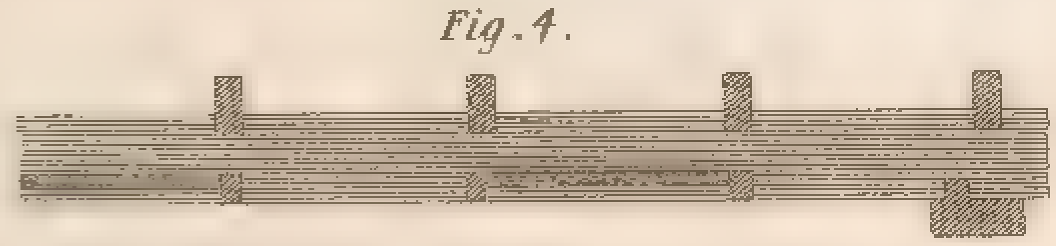


*Fig. 6*

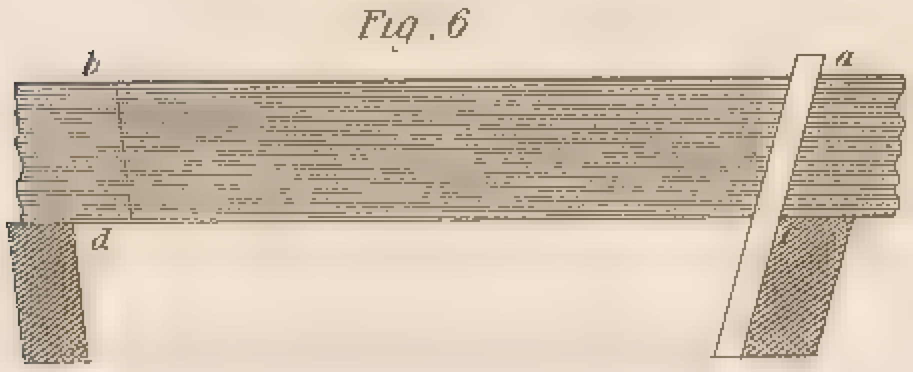



*Fig. 5*

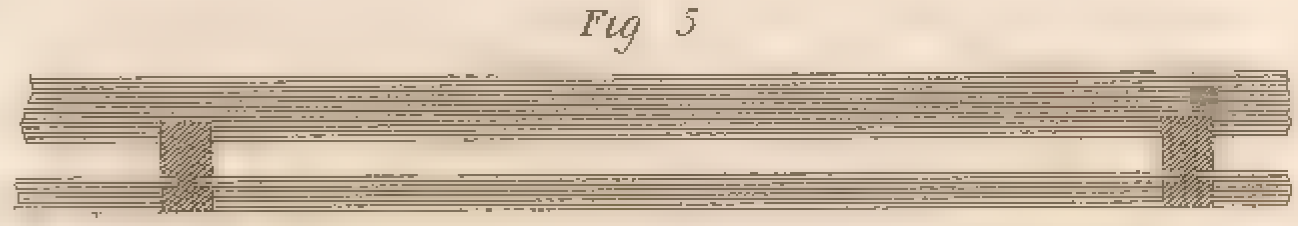
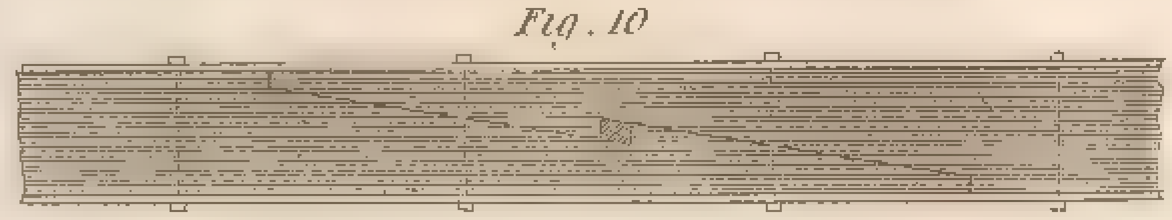


*Fig. 8.*

*Fig. 7.*

*Fig. 9*

*Fig. 10*



*Drawn by P. Nicholson.*

*Engraved by W. Symns.*

*London. Published by Thos. Kelly 17 Paternoster Row January 1, 1822.*

In forming the naked flooring, over rooms of very large dimensions, it is found necessary to introduce large strong timbers, in order to shorten the bearing of the binding-joists; such strong timbers are called *girders*, and are made with mortises, in order to receive the tenons at the ends of the binding-joists, which, by this mean, are greatly stiffened, being much shorter.

The *bridging-joists* are frequently notched down on the binding-joists, in order to render the whole work more steady.

*Figure* 1, *pl.* X, is the plan of a naked floor; *b, b, b,* &c. are the binding-joists; *a, a, a,* &c. are the bridging-joists; *d,* a timber close upon the stair-case. This piece of timber is called a *trimmer:* its use is to receive and secure the ends of the joists, *e, e, e,* &c. upon the landing.

C, C, C, &c. are *wall-plates,* upon which the ends of the binding-joists rest.

In the construction of floors, great care must be taken that no timber come near to a chimney; therefore, the ends of the timbers, as here shown, have no connection with the fire-place, nor with the flues.

The flues, in this plan, are indicated by their being shadowed darker than the other parts of the plan.

*Figure* 2, *pl.* X, is the plan of naked flooring with a girder.

*Figure* 3, shows the manner of framing joists into a girder, with the form of the mortise and tenon. No. 1, is the part of a joist framed into the girder; and No. 2 is a joist out of the mortise.

*Figure* 4, shows the connection of binding-joists, bridging-joists, and ceiling-joists; as, also, the manner of fixing the binding-joists upon the wall-plates, which manner is called *cocking*, or *cogging*. The long dark parts represent the mortises, into which one end of the ceiling-joists are fixed. These long mortises are called *pulley-mortises,* or *chase-mortises.* The ceiling-joists are introduced into common mortises at one end, and the other end of them are let into these long mortises obliquely, and slide along until they are perpendicular.

*Figure* 5, shows how the bridging-joist is let down upon the binding-joist, and how the ceiling-joists are fitted into the binding-joists.

Tumbling in a Joist, is to frame a joist between two timbers, of which the sides, which ought to be vertical or square to the upper edges, are oblique to these edges.

*Figure* 6, shows the method of fitting in a joist between the sloping sides of two others. The first thing done is, to turn the upper edge of the joist upon the top of the two pieces into which it is to be fitted, and brought over its proper place. The next thing is to turn the joist on its under edge, so as to lie over its place; then apply a rule, or straight edge, upon the side of the one piece where the shoulder of the joist is intended to come; then slide the joist until the line drawn come to the straight edge of the rule so applied; then draw a line by the edge of the rule. Do the same at the other end, and the two lines thus drawn will mark the shoulder of the tenon at each end.

## LENGTHENING TIMBERS.

Timbers may be lengthened in various ways, either by making the piece of timber in two or more thicknesses; or by securing one piece to another, with a piece on each side, in order to cover the joint; and by spiking or bolting each piece on both sides of the joint. Sometimes the pieces that are applied on the sides are made of wood; in this case, it is called *fishing the beam:* such modes are used in ships, when their masts, beams, or yards, are broken, in order to mend them. Other modes of continuing the length of timbers or beams is, by splicing them with a long bevel-joint, ending in a sharp edge at the end of each piece. Sometimes the sharp edge of the end of each piece is cut off, so as to form an obtuse angle at the top. Sometimes the splice is so formed as that the two surfaces which come into contact are reciprocally indented into each other, which will add greatly to their security, when firmly bolted together. Every kind of scarf should have a strong iron-strap upon each opposite side, extending in length considerably beyond each joint.

*Figure* 7, *pl.* X, shows the manner of building a beam in three thicknesses; which, being strapped with iron across every joint, and bolted, will be exceedingly strong and firm.

*Figure* 8, exhibits the method of joining timbers by two *tables* and a *key.*

*Figure* 9, the method of lengthening timber by a plain scarf, being cut only with an obtuse angle at the ends.

*Figure* 10, the same kind of scarf, with two tables and a key.

Timbers that are scarfed and strapped ought to be so applied, that the sides which are strapped should be the horizontal sides; for, if otherwise applied, they will be liable to split at the bolting.

But, if the surfaces of the joints are to be placed in a vertical position, there ought to be two straps upon the top and two upon the bottom; each strap being brought close to the vertical face. By this method it will be much stronger than when set in the other position, or with the joint of the scarf horizontal.

## THE ROOFING.

The ROOF is that part of a building raised upon the walls, and extending over all the parts of the interior, in order to protect its contents from depredation, and from the severities and changes of the weather.

The Roof, in Carpentry, consists of the timber-work which is found necessary for the support of the external covering.

The most simple form of roofs is that consisting of a level plane; but this description of roofs is adapted only to short bearings, and is not at all calculated to resist or prevent the torrents of rain or moisture from penetrating into the interior.

The next simple form is that which consists of an inclined plane; and, though well calculated to resist the injuries of the weather, and to afford greater strength than a level disposition of the timbers would supply, it is far from admitting of the utmost strength that a given quantity of timber is

capable of affording: it occasions an inequality, and a want of uniformity and correspondence in the proportions of the fabric, and an unnecessary and unpleasant height of walling. The best figure for a roof is that which consists of two equal sides, equally inclined to the horizon, terminating in the summit, over the middle of the edifice, in a horizontal line, or the *ridge* of the roof, as it is called: so that the section made by a plane, perpendicular to the ridge, is every where an isosceles triangle, the vertical angle of which is the top of the roof. This form is very advantageous, as it regards saving of timber; for it may be executed with the same scantlings, to span double the distance, that the simple sloping roof admits; or, in buildings of the same dimensions, the scantlings of the timbers will be very much diminished.

The antient Egyptians, Babylonians, and other eastern nations, of the remotest antiquity, constructed their roofs flat, as do likewise the present inhabitants of these countries. The antient Greeks, though favoured with a mild climate, yet sometimes liable to rain, soon found the inconvenience of a platform covering for their houses, and accordingly raised the roof in the middle, declining towards each side of the building, by a gentle inclination to the horizon, forming an angle of from 13 to 15 degrees, or the perpendicular height of from one-eighth to one-ninth of the span.

In Italy, where the climate is still more liable to rain, the antient Romans constructed their roofs from one-fifth to two-ninth parts of the span.

In Germany, where the severities of the climate are still more intense than in Italy, the antient inhabitants, as we are informed by *Vitruvius*, made their roofs of a very high pitch. When the pointed style of architecture was introduced into Europe, high pitched roofs were thought consonant with its principles; and they therefore formed, externally, one of the most striking characteristics of the Gothic style.

In their usual proportions, the rafters were equal to the breadth or span of the roof, or the rafters were the sides of an equilateral triangle, of which the spanning line was the base.

During the middle ages this form prevailed, not only in public but in private buildings, from the most stately and sumptuous mansion down to

the humble cottage of the common labourer; and this equilateral triangular roof continued in request until, finally, the pointed style came into disuse.

When the celebrated Inigo Jones introduced Roman architecture, the rafters were made three-quarters of the breadth of the building; and this proportion, which was called *true pitch,* still prevails in some parts of the country where plain tiles are used; subsequently, also, the square seems to have been considered as *true pitch:* but, in large mansions, constructed in the Italian style, roofs of a *pediment pitch,* covered with lead, were introduced.

In the present day, where good slates are to be obtained in abundance, roofs may be covered with them, from the pyramidal equilateral Gothic down to the gently inclined Greek pediment.

With regard to the present practice, the proportion of the roof depends on the style of the architecture of the edifice; the usual height varying from one-third to one-fourth part of the span.

There are, doubtless, some advantages in high pitched roofs, as they discharge the rain with greater rapidity; the snow does not lodge so long on their surface; also, they may be covered with smaller slates, and even with less care, and are not so liable to be stripped by high winds as the low roofs are; but the low roofs bear less weighty on the walls, and are considerably cheaper, since they require shorter timbers, and, of course, smaller scantlings.

The roof is one of the principal ties to a building, when executed with judgement, as it connects the exterior walls, and binds them together as one mass; and, besides the protection it affords the inhabitant within, it preserves the whole work from a state of decay, which would soon inevitably ensue, from the violence of rain or frost, which would operate in a way of rotting the timbers, of destroying the connection in the walls, and would cause them ultimately to fall.

The several timbers of a roof are, *principal rafters, tie-beams, king-posts, queen-posts, struts, collar-beams, straining-sils, pole-plates, purlins, ridge-piece, common-rafters,* and *camber-beams.* The uses of these will appear from the following description of them.

The usual EXTERNAL FORM of a ROOF has two surfaces, which generally rise from opposite walls, with the same inclination; and, as the walls are most commonly built parallel to each other, the section of the roof made by a plane perpendicular to the horizon, and to one of the walls, is an isosceles triangle; the base being the extension from the one wall head to the other. This extension is called the *span of the roof.*

To FRAME TIMBERS, so that their external surfaces shall keep this position, is the business of *trussing;* and the ingenuity of the carpenter is displayed in making the strongest roof with a given quantity of timbers.

All beams, or pieces of timber, from their weight, when supported at the two ends only, acquire a concavity on the upper side; and this concavity is the greater as the distance between the props is the greater. It is, therefore, a grand object to prevent this bending as much as possible. The curvature will take place whether the position of beams be horizontal or inclined; but the same beam will have less curvature, as the angle, to which it is inclined to the horizon, is greater. For, it is evident that, when a beam is laid level, and supported at its extremities, its curvature will be greater than when inclined at any angle, however small; and, again, if it stand perpendicular to the horizon, its curvature will be nothing; that is to say, its curvature will be nothing when the angle of inclination is the greatest.

The curvature which timber obtains by bending is called *sagging.* To prevent timber from sagging, as much as is possible, it must be supported at a certain number of intermediate points or places, besides the two extreme points or places. Now these supports must themselves be supported from some base or other; but, if the resting points or places is upon the surface or surfaces of other timbers, the greatest care must be taken that they do not fall between the extremities of the supporting timbers intended to support the other. That is to say, the lower end of every piece of timber, used as a prop, must rest upon some fixed point; or, otherwise, the propping piece of timber must be so disposed that the pressing forces at each end must be equal to each other.

These are the general principles upon which the strength of roofs depend.

A fixed Point or Place, in Carpentry, is the point or place where two timbers are joined together; and no roof or piece of framing is good, where the end of one piece, used as a prop to another, presses upon a third piece of timber, supporting that prop, between its extremities. The pressing end of every prop ought to rest upon some *fixed point.*

PRINCIPAL RAFTERS are the two pieces of timber, in a framed roof, that form the two equal sides under the covering.

It is evident that the greater the opening is, the more supports each principal rafter will require.

A piece of timber may be supported either from some fixed point above it, or some fixed point below it: if the connecting support be above the piece to be supported, then it is evident that it will act as a string; but, if below the piece to be supported, it is evident that the prop must be an inflexible bar or piece of wood.

Now, therefore, as the principal rafters cannot be supported from above, they must be supported from below; the props must, therefore, be made of some stiff material, as iron or timber, of sufficient thickness; and, because the pressure occasioned by the weight of the covering is uniformly distributed over the principal rafters, these principal rafters must be supported at a certain number of equidistant points, which will depend upon the distance of the walls.

A TIE-BEAM is a piece of timber, connecting the feet of the principal rafters, in order to prevent them from spreading, by the weight of the covering. The *tie-beam* is therefore used as a string, and is in a state of tension.

In order to prevent the sagging of the tie-beam, in very wide houses, it must be supported in one or more places in its length; and, if it cannot be supported from the ground, it must be supported from some *fixed point* or points in the roof itself. The only fixed point is where the two principals meet each other; but this one point will furnish as many supports to the tie-beam as we please; then every one of these points in the tie-beam are *fixed points:* from each of these fixed points in the tie-beam, the principal rafters may be supported; or in as many points, or from any convenient fixed point,

in the tie-beam, the principal rafter above may be supported, in as many points in its length as we please.

No direct rule can be given for the disposition and position of supporting timbers: the best way to judge of this is, such a disposition as will make the connecting timbers as short as possible, and the angles as direct as possible. Oblique or acute angles occasion very great strains at the joints, and should therefore be avoided. One grand principle to be obtained, in every frame or roof, is, to resolve the whole frame into the least number of triangles, which must be considered as the elements of framing. Quadrilateral figures must be avoided, if possible; and this may be done by introducing a diagonal, which will resolve it into two triangles; for, without this, a four-sided figure will be moveable round its angles. Sometimes it may be necessary to resolve a quadrangular piece of framing into *four* triangles, by means of two diagonal pieces, particularly when this figure occurs in the middle of a roof.

The principles of framing being once understood, a little practice in designing will soon enable the artizan to judge of the proper disposition of timbers, so as to produce a good design, if not the best possible.

A KING-POST, or PRINCIPAL POST, is a vertical piece of timber, extending from the meeting of the two principal rafters to the tie-beam, for the purpose of supporting the tie-beam in the middle.

The KING-POST is, therefore, in a state of tension; and, consequently, a string, which will not lengthen, may be used as a tie-beam; and this string may be a slender bar of wrought iron, or any tenacious material, that will not be liable to greater extension when stretched or drawn in length.

The principal rafters are frequently supported from one or more points in the king-post: but it is evident that they must be supported exactly in the same manner when the supporting points in the king-post are between its two extremities; so that the principal rafters may produce equal and opposite pressures on each side of the king-post.

Each of the principal rafters may be supported in as many points as we please, either from one point in the king-post, or from as many points as the number of points to be supported; or, as has been said before, either from one

fixed point, or from as many fixed points, in the tie-beam, as the number of points to be supported; and, in short, the principal rafters may be supported from any fixed point whatever, from the king-post, or tie-beam, or from both. This very circumstance points out a vast variety of designs for roofs.

QUEEN-POSTS are two pieces of timber, equidistant from the middle of the truss; the one suspended from the head of one of the principal rafters, and the other from the head of the other, with a level piece of timber between them.

The Queen-posts, therefore, divide the internal space of the frame into three compartments, of which the two extreme ones are right-angled triangles, and the middle one a rectangle.

The use of the queen-posts is similar to that of the king-posts; *viz.* for furnishing a general support for the principals, at different points between the ends, by connecting timbers, and supporting the tie-beam between its extremities.

STRUTS are those props which support the principal rafters, in one or more points, so as to divide them into equidistant parts.

Struts are generally disposed in pairs, equally inclined to the vertical line, which divides the truss into two equal and similar parts; and which, therefore, divides the two beams into two equal lengths. Struts are necessary in roofs where the span is great; and the greater the span or distance of the walls, the greater the number of struts will be required; for, in this case, more points in the principals will have to be supported.

A COLLAR-BEAM is the piece of timber framed between two queen-posts.

A *collar-beam roof* is necessary where the roof is to have a platform, or flat for walking upon, or wherever rooms are required in the roof.

A STRAINING-SILL is a horizontal piece of timber, disposed between the feet of the queen-posts, to counteract the efforts of the struts, in pushing the principals nearer to each other.

Having thus noticed the several parts of a truss, it may be proper to observe that all king-posts, queen-posts, and tie-beams are *ties;* and, therefore, a

string incapable of farther extension than is sufficient to bring it to a straight line. A chain, or a slender bar of iron, will answer the same purpose as well as a piece of timber, or other such inflexible material. It is also to be remarked that all collar-beams, principal rafters, and struts, are *straining pieces;* which are, therefore, necessarily constructed of an inflexible material, such as wood, or a stiff piece of iron. It may be further observed that, in complex frames, such as centering to large arches or bridges, in the act of building, the same timbers, in different stages of the work, sometimes perform the office of ties, and sometimes that of straining pieces; and, in the transition of office, must be sometimes in a neutral state. The material employed in such situation must, necessarily, be inflexible. This is to be recommended not only here, but in every doubtful case, or where it is uncertain whether the part of the truss requires to be a tie or a straining piece.

A POLE-PLATE is a beam over each opposite wall, supported upon the ends of the tie-beam, or upon the feet of the principal rafters.

PURLINS are horizontal pieces of timber, supported by the principal rafters.

A RIDGE-PIECE is a beam at the apex of a roof, supported by the king-post, or by the heads of the principals.

COMMON RAFTERS are inclined pieces of timber, parallel to the principal rafters, supported by the pole-plates; the purlins and the ridge-piece, for supporting the covering, the material of which is sometimes large slates, extended from rafter to rafter, and sometimes smaller slates, nailed upon boarding, battening, or hung to lath, and these nailed upon the common rafters.

JOGGLES are the joints at the meeting of struts, king-posts, queen-posts, and principal rafters; and, indeed, all the joints of a roof may be termed *joggles.* The best form of the joggles is that which is at right angles to the lengths of the struts or rafters, or at right angles to the tenoned piece: but this position cannot, at all times, be obtained, from the want of sufficient substance of timber: in this case, the joint is made either oblique, or the upper part in a line with the side of the piece which has the mortise, and the lower

part perpendicular to the sides of the tenoned piece : or the joint is sometimes made partly parallel, and partly perpendicular, to the mortised piece. When the joint is oblique, the force of the tenoned piece, in the direction of its length, causes the end to slide upon the abutment, towards the side which contains the obtuse angle : but this is, in some degree, counteracted by the resistance of the tenon on the lower end of the mortise. However, with regard to the stress of the timbers in a frame, the abutting joint is of little importance. *M. Perronet*, the celebrated French engineer, formed the abutments, and, consequently, the joggles, in the arches of circles, making the centre at the other extremity.

CAMBER-BEAMS are those timbers which are supported upon purlins over the collar-beams, and support the boarding for a leaden platform : for this purpose they have an equal declivity from the middle, in order to cause the water from rain or snow to descend equally on each side of the roof.

COCKING, OR COGGING, is the form of the joints, which the tie-beams and wall-plates make with each other ; and here, as in every other case of jointing, the parts must be reciprocally reversed to each other, so that the protuberant part or parts of the one are the raised or indented parts of the other. The parts which come in contact are plane surfaces ; those which form the bottom or bottoms of the recess or recesses are parallel to, and those which form the sides perpendicular to, the surfaces, from which the jambs are made. The best method is, by cutting a groove, across the fibres, in the beam to be let down, to correspond to a rising in the plate formed by recessing the plate, on each side of the rising. Another method is by an external and internal dovetail : but this method is almost antiquated.

## PARTICULAR OBSERVATIONS ON ROOFS.

GABLE-ENDED ROOFS, unless properly supported by ties, are liable to thrust out the walls, and particularly when the walls are very thin, or the distance between them very great. A HIPED ROOF, over a rectangular plan, when the jack-rafters are well secured to the principals, produces less lateral pressure

on the walls than a gable-ended one upon the same plan. A hiped roof, upon a square plan, produces less lateral pressure upon the walls than an oblong of the same area. With regard to roofs executed upon regular polygonal plans of the same area, that which has the greater number of sides produces less lateral pressure on the walls than that which has fewer sides; and, when the number of sides are very many, the polygon may be considered as a circle; and, consequently a circular roof will give less lateral pressure upon the walls than a polygonal one of any number of sides, however great.

In the execution of all these, however, it will be necessary that a wall-plate should be formed to the plan, and well connected, not only between each of the angular points, but also at the angular points themselves; for, when the building is carried up on a polygonal plan, every two adjacent hips will act in the same manner as the two principals in a framed roof; and, therefore, every side of the wall-plate will be a tie; and, consequently, if not properly joined, the walls will be liable to be rent.

## COVERING OF CIRCULAR ROOFS.

Circular Roofs may be covered upon two different principles; one is, by supposing the axal section to be divided into a number of small equal parts, and the roof cut by planes through the points of division, parallel to the base; and, by considering the frustums of the solid as so many frustums of a cone, the covering of each respective part will be found. The other principle is by dividing the circumference of the base into a number of small equal parts, and supposing axal sections to be made through the points of division; then, by considering the surface of each axal portion as the surface of a cylinder, the covering will be found. The distance between the points of division, in the former case, must be less than the breadth of the boards which are to form the envelopes of the covering, in order to make the convex edge of the board: this distance must, therefore, be less, as the length of the boards is greater. In the latter case, the distances between the points of division may be exactly

# GEOMETRICAL LINES.

## FOR ROOFS.

Fig 1

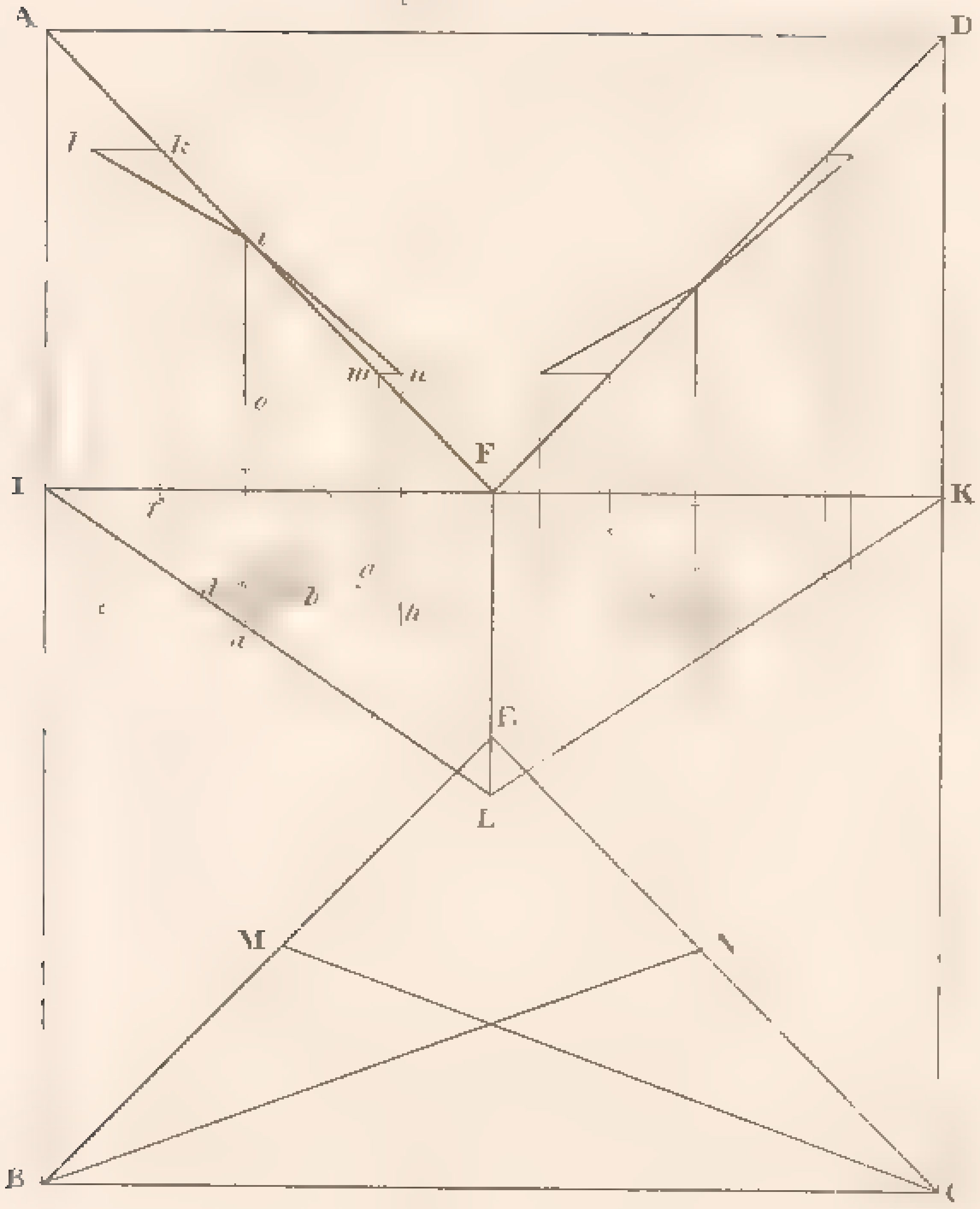



Fig 2

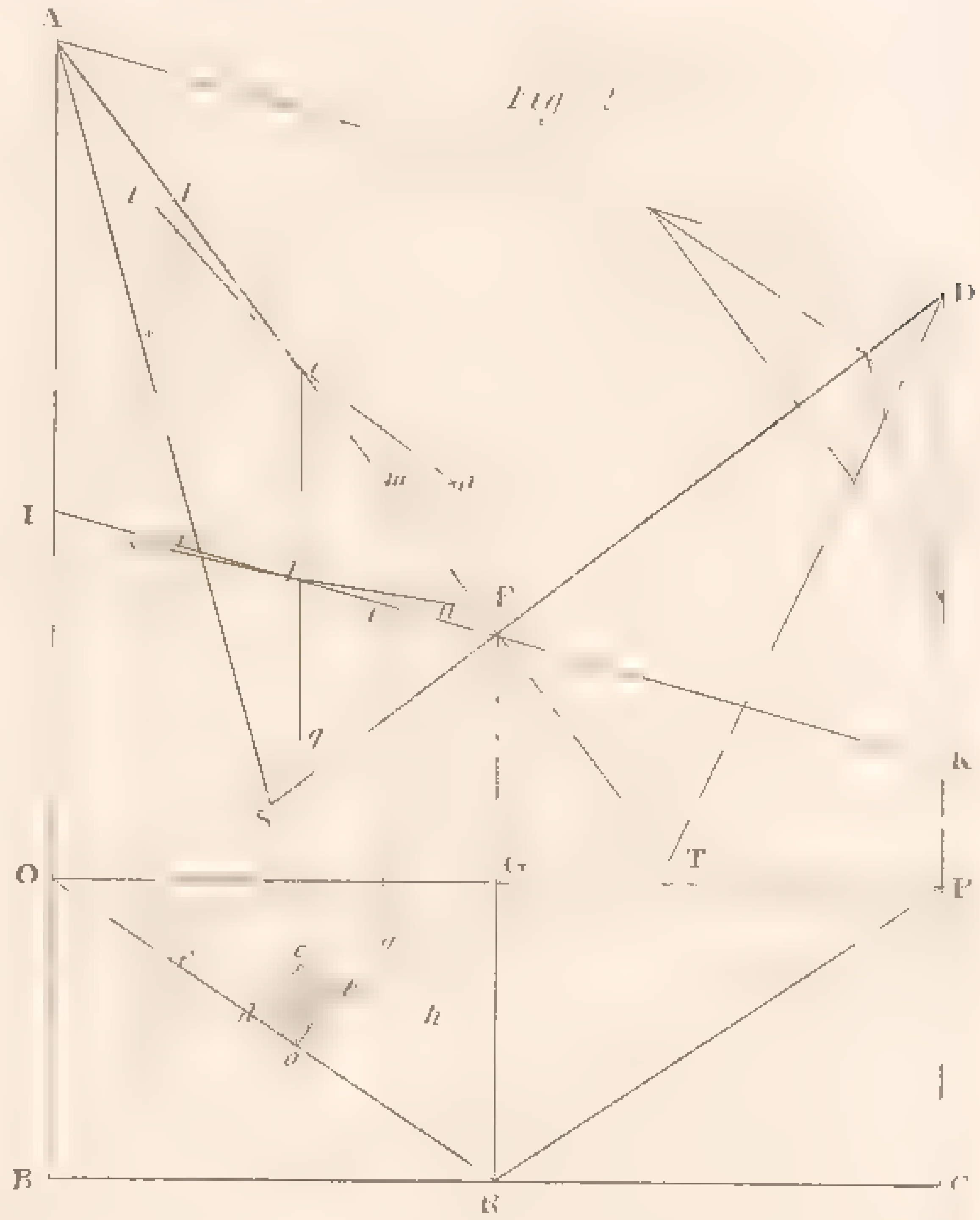



Fig 3.

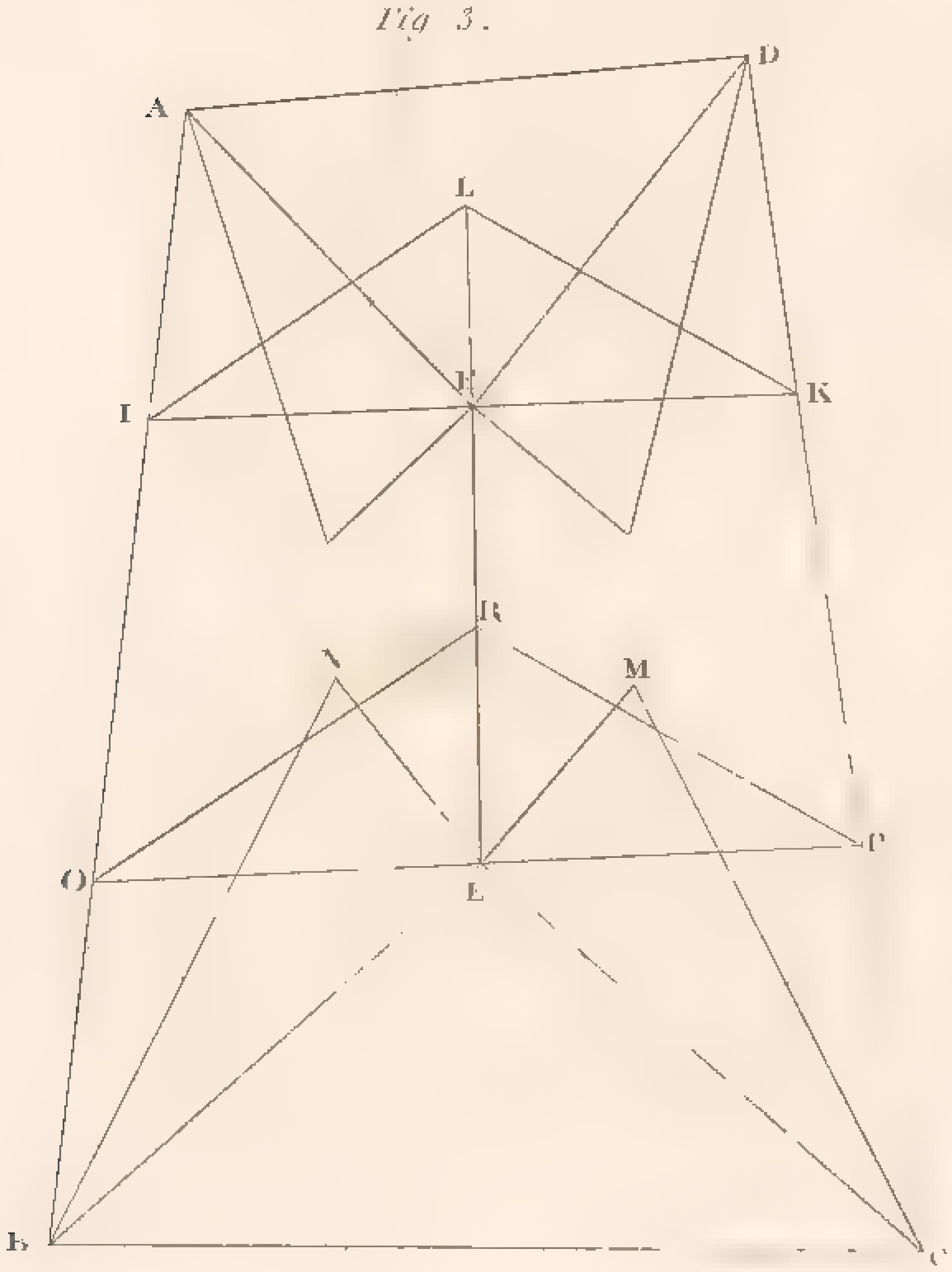
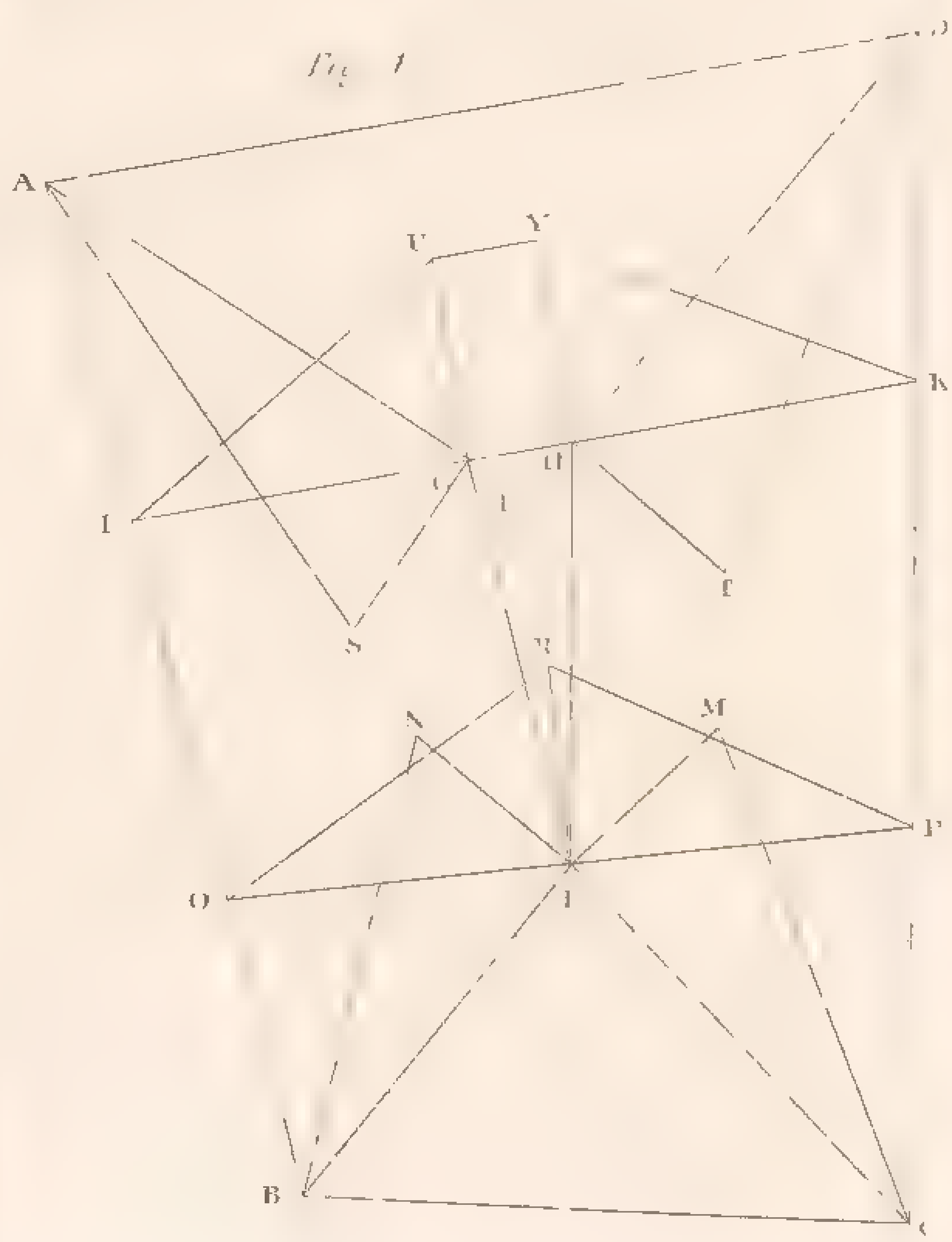



Fig 4




*Drawn by P. Nicholson* *Engraved by W. Symns*

equal to the breadth of the boards. It is true that the surface of each part is spherical or convex, and therefore can neither be considered as the frustum of a cone, nor that of a cylinder: but, if the distance between the divisions be small, the surfaces will be almost straight in all the axal sections; so that there will be no practical difference, even though the widest boards be used in moderate-sized works. The boards which thus form the envelopes must be thin, in order that they may comply with the surface of the circular roof to be covered. It is here proper to notice that, when boards are bent, so as to form a surface either concave or convex, they are much stronger than if the surface were a plane, even though the ribs were at the same distance in both: but, in order to make the boards bend regularly and truly, the ribs ought to be disposed at a nearer distance, even at the widest place, which is at the bottom, than the rafters of a common roof. When the ribs are disposed in axal planes, they will come in contact with each other at the top, unless they terminate upon a circular kirb, of a diameter sufficient to prevent their doing so; but, as the intervals at the top are always much less than at the bottom, the ribs are sometimes discontinued, in order to reduce the intervals nearer to an equality of breadth throughout the length of each: the execution in this way will save the timber-work, and, consequently, lessen the expenses. Sometimes the ribbing of circular roofs consists of only several principal axal ribs, and the intervals filled in with jack-ribs; which, if the surface to be covered be spherical, are portions of less circles of the sphere, and are disposed in parallel vertical planes.

### PROBLEM 1.

To find the bevels for cutting the various timbers in a hiped roof, and the backing of the hips (*pl.* XI, *figures* 1, 2, 3).

Let ABCD, *figures* 1, 2, and 3, be the outlines of the wall-plates, AF, DF, and BE, CE, the seats of the hips, and EF the seat of the ridge-piece.

To find the length of any rafter, draw a line from the one extremity of the seat of that rafter, perpendicular to that seat, and make the height of the perpendicular equal to the height of the roof; join the point of extension

and the other extremity of the seat, and the line thus joined is the length of the rafter as required.

*Example* 1; *figure* 1.—Find the length of the common rafters standing upon IK; divide IK into two equal parts in the point F: draw FL perpendicular to IK; make FL equal to the height of the roof, and join IL or KL; then IL or KL is the length of each rafter.

*Example* 2; *fig.* 2.—Find the length of the hip-rafter standing upon AF. Draw FS, perpendicular to AF: make FS equal to the height of the roof; join AS, and AS is the length of the hip.

### PROBLEM 2.

To find the bevels of a purlin upon a hip-rafter, giving the seat of a common rafter, and the seat of the hip-rafter, and the angle which the common rafter makes with its seat.

Place the section-purlin in its real position with respect to the common rafter. Produce that side of the section of the purlin, of which the bevel is required, upon the hip toward the seat; from one extremity of the line thus produced, and, with the length of the said line as a radius, describe a circle. Draw three lines, parallel to the wall-plate, to meet the hiped line: viz. one from the centre of the circle, one from the point where the line meets the circle, and the third a tangent to the circle. From the point in the seat of the hip-rafter, where the middle line meets the said seat, draw a line perpendicular to that middle line, to meet the tangent; join the point where this perpendicular meets the tangent to the point where the line drawn from the centre meets the seat of the hip-rafter, and the angle formed by the line thus joining, and the line drawn from the centre of the circle, will be the bevel of the purlin.

*Example; pl.* XI, *fig.* 1.—AF being the seat of a hip-rafter, IF that of a common rafter, and FIL the angle which the common rafter makes with its seat, and *a b c d* the section of the purlin.

Now suppose it were required to find the bevel of that side of the purlin represented by *a d*.

Produce $ad$ to any point, $f$; and from $a$, with the radius $af$, describe a circle, $fgh$. Parallel to the adjacent wall-plate, AB, draw three lines to cut the seat, AF, of the hip; *viz.*, from the centre, $a$, draw $ai$; and from the point $f$, where $af$ meets the circle, draw $fk$, the former cutting the seat in $i$, and the latter in $k$. Draw $kl$ perpendicular to $fk$, and draw the tangent $el$, cutting $kl$ in $l$; and join $il$; then $lia$ is the angle required.

In the same manner, by producing $ab$, we shall find the angle formed upon the end of the side, of which its section is $ab$.

In order that the different inclined planes, which form the sides of a roof, should have an equal inclination to the horizon, the seats of the hip-rafters ought to bisect the angles of the wall-plates.

When a roof is wider at one end than at the other, in order, as in *fig.* 3, to prevent its winding, let IK and OP be the seats of the two common rafters, passing through each extremity of the ridge-piece, and let the rafters IL and KL be found as before; divide OP into two equal parts, in E; draw ER perpendicular to OP. Make the angle EPR equal to the angle FKL; then ER will be the height of the roof upon the seat OP.

If this should be objected to, because it makes the ridge higher at one end than at the other, let E, *fig.* 4, be the end of the seat of the ridge next to the narrow end of the roof.

Bisect all the four angles of the roof by the straight lines AF, BE, CE, DF; and, through E, draw EG, parallel to AB, cutting AF in G; and draw EH, parallel to CD, cutting DF in H; and join GH: then GH will be parallel to AD. This is true, because, since all the angles are bisected, if we imagine perpendiculars drawn from E to the three sides, the three straight lines thus drawn will be equal: and, because EG is parallel to AB, the perpendiculars drawn from the points E and G, to the straight line AB, are equal; from the same reason, because EH is parallel to CD, the perpendiculars drawn from the points E and H, to the straight line CD, are equal; therefore the perpendicular drawn from the point G, to the straight line AB, is equal to the perpendicular drawn from H to the straight line CD. And, since the angles BAD and CDA are bisected by the straight lines AG and DH, the two

perpendiculars, drawn from G, to the sides AB and AD, are equal; as also the two perpendiculars from the point H to the sides DA and DC: but the perpendicular drawn from G, to the side AB, is equal to the perpendicular drawn from H to the side CD: therefore the perpendiculars, drawn from the points G and H, to the straight line AD, are equal to each other; but, when the perpendiculars drawn between two straight lines are equal, these two straight lines are parallel: therefore the straight line GH is parallel to AD.

Whence, if all the angles of a roof be bisected, and if any point be taken in any one of the bisecting lines, and if a line be drawn through the point thus assumed, parallel to one of the adjacent sides, to meet the next bisecting line, and so on from one to another, till only one line remains to be drawn; then, if the point assumed be joined to the point where the parallel meets the last bisecting line, the line thus joining will be parallel.

## OF NICHES.

NICHES are ornamental recesses formed in walls, in order to enshrine some ornament, as a statue, or elegant vase. They are often constructed in thick walls, in order to save materials in masonry, or brick-work.

Niches are sometimes constructed of ribs of timber, and lathed and coated over with plaster, which forms the surface to be exhibited.

The plans or bases of niches are always some symmetrical figure; as a rectangle, a segment of a circle, or one of an ellipse.

All the sections of niches, parallel to the base, are similar figures; and all the sections parallel to the base, to a certain distance, are equal. Niches sometimes terminate upwards in a plane surface, and sometimes in an ellipsoidal surface; but most frequently in the portion of a spherical surface: so that, as the faces of walls are generally perpendicular to the horizon, the aperture in the face is either a rectangle, or a rectangle terminating in the

segment of a circle, or in the segment of an ellipse. Two of the sides of the rectangle are perpendicular to the horizon.

Niches are always constructed in a symmetrical form; *viz.* if a vertical plane be supposed to pass through the middle point of the breadth, perpendicular to the surface of the wall, it will divide the niche into two equal and similar parts; or, if any two points be taken in the breadth, equi-distant from the sides of the niche, and if two vertical planes be supposed to pass through these points, perpendicular to the surface of the wall, the sections of the niche will be equal and similar.

Niches are placed either equi-distantly, in a straight wall, or round a cylindrical wall, dividing the circumference into equal parts: sometimes they are placed in an elliptic wall. In the latter case, however, they ought not to divide the circumference into equal parts, but to be at an equal distance from each extremity of the major axis. Niches are frequently constructed in polygonal rooms; a niche being placed in the middle of each side of the prismatic cavity. The opposite sides of such rooms are always equal and similar rectangles. The plans are either hexagonal or octagonal; but, most frequently, of the latter form.

The principles of forming the ribs, for the heads of spherical niches, are drawn from the following considerations:

All the sections of a sphere, made by a plane, are circles; therefore the edges of the ribs to be lathed ought to be portions of circles.

The ribs of niches may be placed either in vertical planes, or in horizontal planes; and, indeed, in any manner, so as to form the spherical surface as required: it will be most convenient, however, to dispose the ribs either in vertical planes, or in planes parallel to the horizon, as the case may require.

One of the most easy considerations for the ribs of a niche, when placed in vertical planes, is to suppose them to pass through a common line of intersection; and, if this line passes through the axis of the sphere, the ribs will be all equal portions of the circumference of a great circle of the sphere; and will, in consequence, be very easily executed. In this case, the square edges of

the ribs will range, or form the surface of the niche. This position of the ribs is therefore very convenient for forming them, as it not only requires less time to execute them, but much less wood will be required.

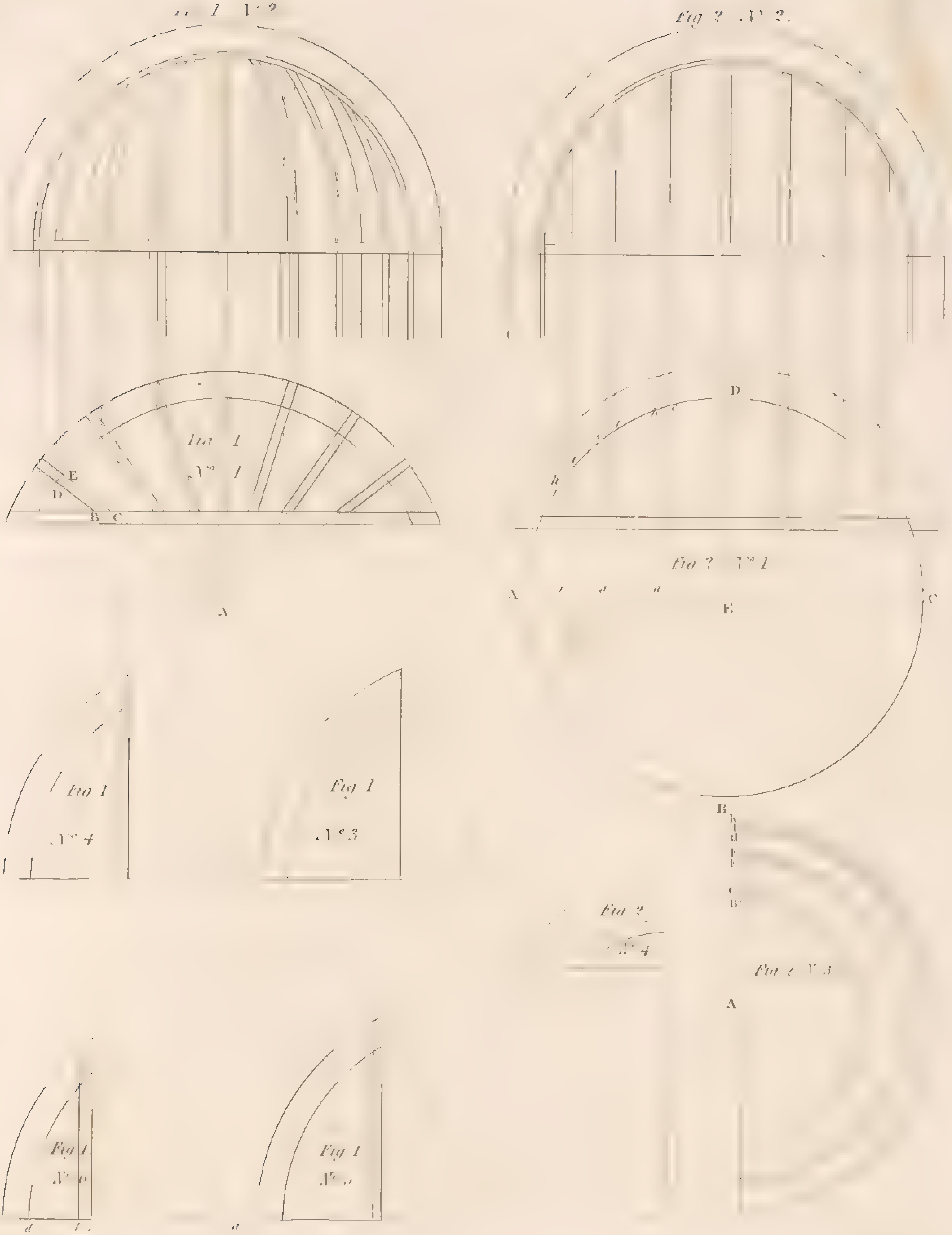
There is another position of vertical ribs, which is frequently convenient; that is, by placing the ribs in equi-distant planes, perpendicular to the surface of the wall; and, consequently, when the surface of the wall is a plane, the planes of the ribs will be all parallel.

*Figure* 1, in *pl.* XII, exhibits the plan and elevation of a niche; the ribs are disposed in vertical planes, which intersect in the centre of the sphere. The plan, No. 1, is the segment of a circle; and, in consequence of this, the back ribs are of different lengths, and will therefore meet the front rib in different places, as shown in the elevation, No. 2. For, if the plan had been a semi-circle, all the back ribs would have necessarily met the front rib in the middle of its circumference. Numbers, 3, 4, 5, 6, (*fig.* 1,) exhibit the ribs, as cut to their proper lengths, according to the plan, No. 1. Thus, let it be required to find the rib standing upon the plan BCED, of which the sides BD and CE are equi-distant from the line that passes through the centre A. In No. 6 draw the straight line *ad*, in which make *ac*, *ab*, *ad*, equal to AC, AB, AD, No. 1: in No. 6, from the point *a*, as a centre, describe an arc of a circle; from the points *b*, *c*, draw two straight lines, perpendicular to *ad*, cutting the arc; then the portion of the arc, intercepted between the point *d* and the perpendicular drawn from the point *b*, is the *arris line* next to the front, and the part intercepted between the point *d* and the perpendicular is the arc forming the arris line next to the back; so that the extremities of the perpendiculars drawn from *b* and *c*, give the extremities of the joint against or upon the front rib.

As to the form of the back edges of the ribs, they may be curved or formed in straight portions. In this manner all the other ribs will be formed; as is evident from the preceding explanation.

*Figure* 2, *pl.* XII, exhibits the plan and elevation of a niche, with the method of describing the ribs when they are disposed in parallel planes. No. 1 is the *plan*, No. 2 the *elevation*, and Nos. 3 and 4 the method of

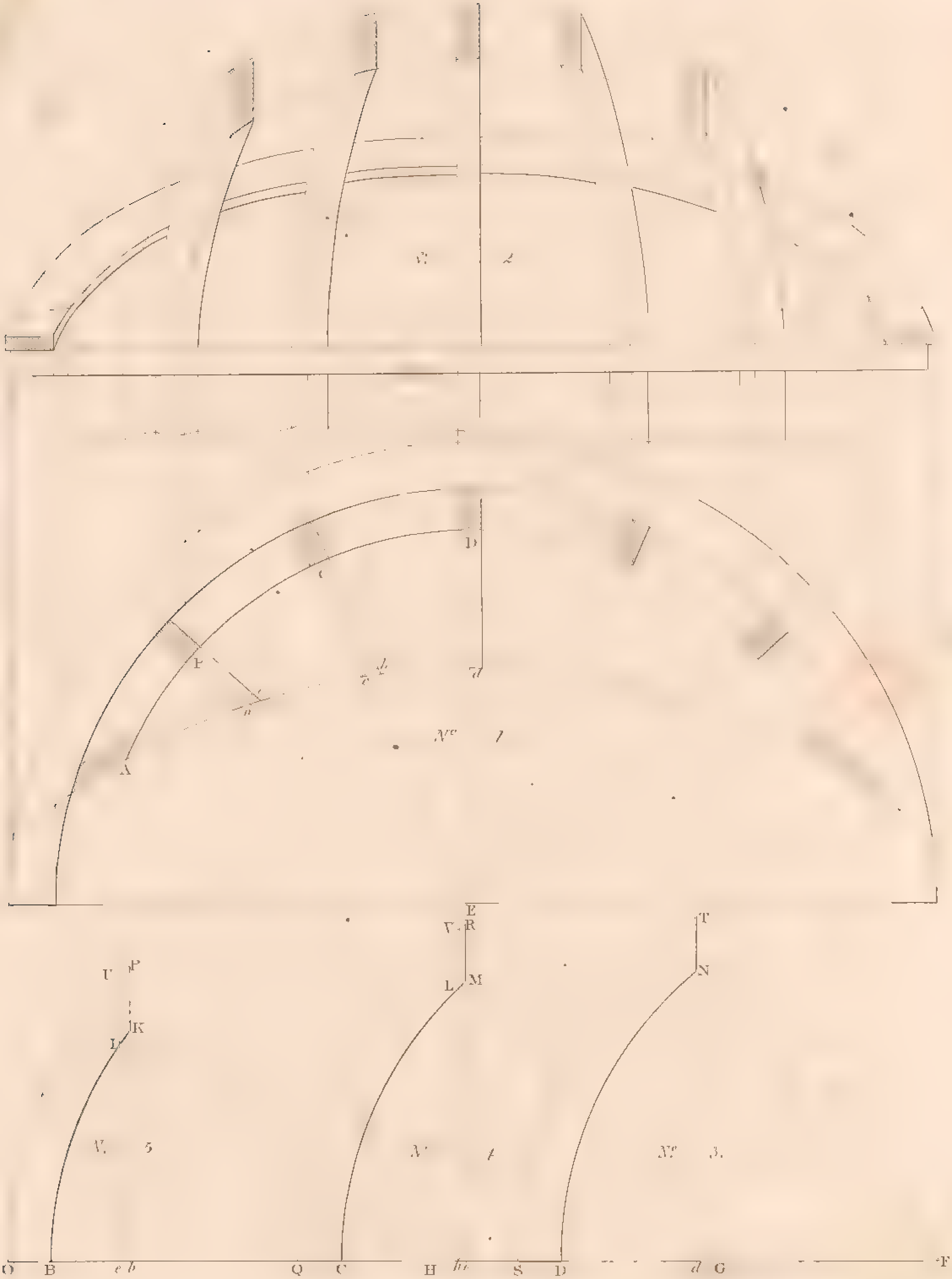
# NICHES.




Drawn by P. Nicholson.

Engraved by W. Symns

# NICHES.



*drawing the ribs.* The lengths of the bases of the ribs, in Nos. 3 and 4, are taken from the plan No. 1; as AK, AI, AH, AF, AE, AC, AB, are respectively equal to ED, *ac, ab, af, ae, ai, ah,* in the base No. 1. The two distances which approach near to each other show the quantity of bevelling. With these distances, from the centre A, No. 3, describe as many semi-circles as there are points; then the double lines will represent the quantity of bevelling, or the distance from the square edge. No. 4 shows one of the ribs by itself.

To DRAW THE RIBS OF A SPHERICAL NICHE, in a circular wall. *Plate* XIII, *Nos.* 1, 2, 3, 4, 5.

Let No. 1 be the plan of the niche, and that of the wall A*bcd*, &c. the base line of the circular wall; ABCD the base line of the spherical niche; and A, B, C, D, &c. the bases of the ribs, of which the sides are all supposed to stand in a vertical plane; and a plane passing through the middle of the thickness of each rib, parallel to the sides of that rib, is supposed to pass through the centre of the sphere; and, therefore, the bases of these planes will pass through the point E, which is the projection of the centre of the sphere, on the horizontal plane, where the cylindrical and spherical surfaces meet each other; and this we may suppose to be the plane of the paper.

Now, since all sections of the sphere are circles, all the edges of the ribs of the niche will be circular; but, because all the circles pass through the centre of the sphere, the edges of the ribs of the niche must be all segments of great circles of the sphere; and, therefore, they must all be described with one radius, which is equal to that of the arc A, B, C, D, &c., and, consequently, with the radius EA, EB, EC, ED, &c., as at No. 3, No. 4, No. 5, &c.; therefore, from F, G, H, as centres, describe the arcs DN, CM, BK; and draw FD, GC, HB. Produce FD to S, GC to Q, and HB to O. In the radius FD, No. 3, make F*d* equal to E*d*, No. 1, and draw *d*T perpendicular to FD, cutting the arc DN at N; then DN will be the under edge of the rib which stands upon *d*D, its plan. In No. 4, upon the radius CG, make C*h*, C*c*, equal to the plan of each side of the rib which stands upon C, No. 1; and, in No. 4, draw *c*R, *h*V, cutting the arc CM at L and M.

In like manner, in No. 5, make B*e*, B*b*, each equal to the side of the rib B, in the plan, No. 1; and, in No. 4, draw *b*P, *e*U, perpendicular to BH, cutting the arc BK in I and K. Then the backs of these ribs may either be the arcs ST, QR, OP, or may have any outline whatever; but, for the convenience of what will be presently shown, in the fixing of the ribs, it will be proper to make them all circular arcs of one radius, which will make them sufficiently strong. Then IPKU is the representation of the top of the rib, which top coincides with the face of the wall, and, consequently, the distance between the lines LV, MR, is the quantity which this rib, now under description, must be bevelled. In like manner IKPU is the representation of the upper end of the rib which stands upon its plan B, and where it falls in the surface of the wall.

The back of the ribs being made circular, and of one radius, they will all coincide with another spherical surface: if, therefore, the back ribs are fixed at their bases, the inner edges will be brought to the spherical surface, by fixing a rib, whose inner concavity has the same radius as the backs of the ribs, upon the backs of these ribs; so that the plane, passing through the middle of its thickness, parallel to its sides, may pass through the centre of the sphere. In other respects, the plane of this fixing rib may have any other position whatever, besides what has now been described.

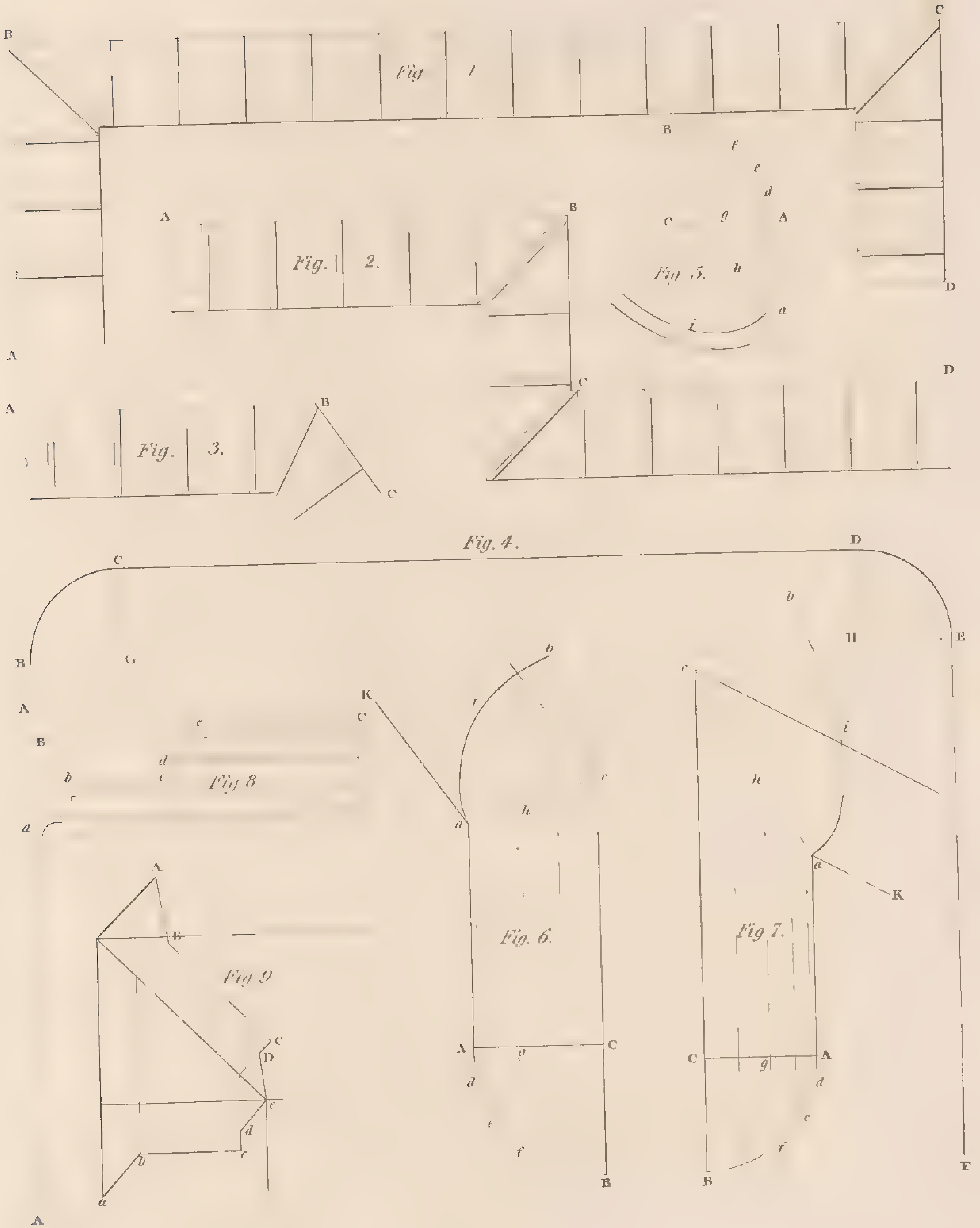
## BRACKETING FOR COVES AND CORNICES.

Cove-bracketing is the finish of the top of the faces of a room, adjacent to the cornice, and consists, generally, of the concave surface of a cylinder; though it may be, occasionally, that of a cylindroid; and the latter surface will, in many cases, have the appearance of greater ease than the surface of a cylinder.

All the vertical sections of coved ceilings, perpendicular to the wall, are equal and similar figures, alike situated to the surface of the wall, and equidistant from the floor.

PLATE. XIV.

# BRACKETING FOR CORNICES AND COVES.




Drawn by P. Nicholson

Engraved by W. Symns

London, Published by Thos. Kelly, 17 Paternoster Row, January 1, 1822

The CORNICE of a room has the same properties; that is, its vertical sections, perpendicular to the surface of the wall, are equal and similar figures; and their corresponding parts are equi-distant from the wall, and also from the floor.

As the coves and cornices of rooms are generally executed in plaster, when they are large, in order to save the materials, the plaster is supported upon lath, which is fastened to wooden brackets, and these again to bond-timbers, or plugs in the wall: for this purpose the brackets are equi-distantly placed, and are about three-quarters of an inch within the line of the cornice; and, in order to support the lath at the mitres, brackets are also fixed in the angles.

In *fig.* 1, *pl.* XIV, ABCD is the plan of the faces of the walls of a room. The plan of the bracketing is here disposed internally, and the angle brackets are placed at B and C.

In *fig.* 2, ABCD is the plan of part of one side and the chimney-breast; and here, on account of the projection, we have one internal angle and one external angle. We may here observe, that the angle bracket of the external angle is parallel to that of the internal angle.

*Figure* 3 exhibits a bracket upon a re-entering obtuse angle.

In *fig.* 4, ABCDEF is part of the section of a room; CD is the ceiling line; CB and DE are the sections of the coves; BA and EF are portions of the wall-lines.

*Figure* 5 shows the construction of a cove-bracket at a right angle. Let AC be the projection of the cove, and let A*a* be part of the wall-line: make A*a* equal to AC, and join *a*C; on the base AC describe the bracket AB, which is here the quadrant of a circle. In the arc AB take any number of points, *d*, *e*, *f*, &c., and from these points draw lines parallel to A*a*; that is, perpendicular to AC, cutting both AC and *a*C in as many points; from the points of section in *a*C draw lines perpendicular to *a*C, and make the lengths of the perpendiculars respectively equal to those contained between the base AC and the curve AB; and, through the points of extension, draw a curve; and the curve, thus drawn, will form the cove in the angle, as required to be done.

*Figure* 6, exhibits the construction of a bracket for an external obtuse angle, A*a*K being the wall-line.

*Figure* 7, exhibits the construction of a bracket for an external acute angle.

*Figure* 8, exhibits the section of a large cornice, where the lines within the mouldings form the bracket required.

*Figure* 9, shows the construction of the angle-bracket for a cornice in a right angle.

To form the bracket in the obtuse or acute angle, take any point *f* (*figures* 6 and 7,) in the given cove, and draw F*h* parallel to A*a*, cutting the base AC of the given bracket in *g*, and the base *ac* of the angle-bracket in *h*: draw *hi* perpendicular to *ac*, and make *hi* equal to *gf*; then will *i* be a point in the curve. In the same manner we may obtain as many points as we please.

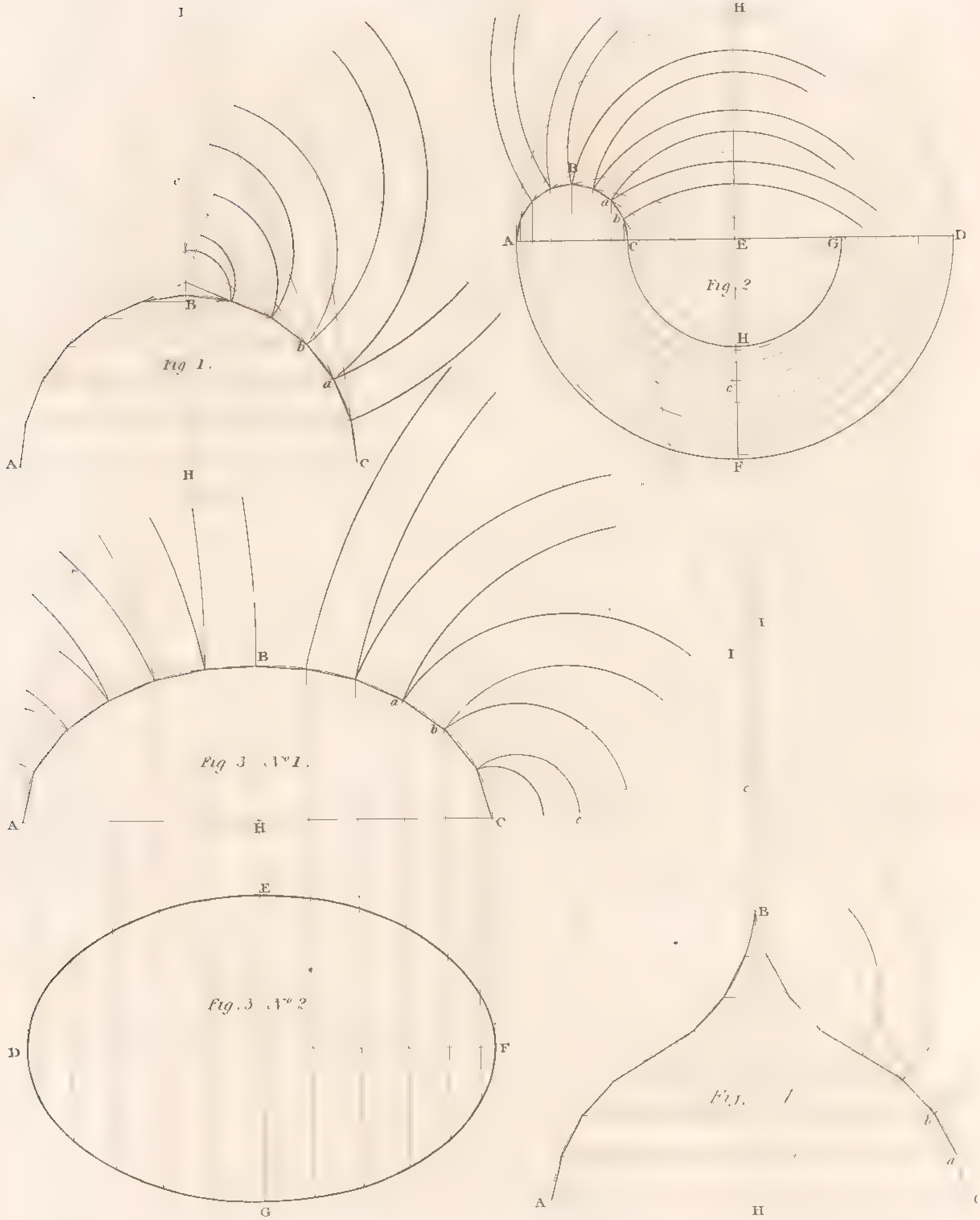
This description also applies to the construction of an angle-bracket of a cornice; the only thing to observe with regard to this is, to make all the constructive lines pass through the angular points in the edge of the common bracket.

In the construction of angle-brackets, it will be the best method to get them out in two halves, and so range each half to its corresponding side of the room; and, when they are ranged, we have only to nail them together.

## METHODS OF BOARDING CIRCULAR ROOFS.

With regard to the boarding of roofs for slates, there are two principles; first, it is evident that, if a round solid be cut by two planes, each parallel to the base, the portion of the surface of the solid, between these planes, will nearly coincide with a conic surface, contained between sections perpendicular to the axis of the cone, of the same diameter each as those made by cutting the round solid; therefore the whole of the round solid may be looked upon as so many conic frustums, lying upon one another; therefore, to cover all the conic frustums is to cover the round solid.

# METHODS FOR COVERING CIRCULAR ROOFS.




Drawn by P. Nicholson

The other method of covering a round solid is to suppose the base divided into equal parts, and the solid to be cut by planes passing through the points of division, and through the fixed axis; then the surface of the body will be divided into as many equal and similar parts; so that, if any one of these portions of the solid be covered, the cover will, of course, fit any other portion thus divided; and, as all the horizontal sections of each portion of the solid is the sector of a circle, the chords of all the sectors will be parallel to each other; therefore the curved surface will be nearly prismatic. This, therefore, affords another method of forming the boarding.

The first of these methods is called the *horizontal method,* and the second the *vertical method,* of covering a dome.

In *fig.* 1, *pl.* XV, let ABC be a vertical section of a circular dome, through its axis; and let it be required to cover this dome horizontally; bisect the base, AC, in the point H, and draw HI perpendicular to AC, cutting the semi-circumference in B. Divide the arc BC into such a number of equal parts that each part may be less than the breadth of a board; that is to say, allowing the boards to be of a certain length, each part may be of the proper width, allowing for waste: Then if, between the points of division, we suppose the small arcs to be straight lines, as they will differ very little from them, and if horizontal lines be drawn through the points of division, to meet the opposite side of the circumference, the trapezoids will be the sections of so many frustums of a cone, and the straight line HI will be the common axis for every one of these frustums.

Now, therefore, to describe any board, which shall correspond to the surface of which one of the parts, $ab$, is the section, produce $ab$ to meet HI in $c$; then, with the radii $cb$, $ca$, describe two arcs; then radiating the end to the centre, the lines thus drawn will form the board required.

In the same manner any other board may be found; as is evident from the principle described.

TO FIND THE FORMS of the BOARDS for covering an ANNULAR VAULT (*pl.* XV, *fig.* 2).

Let AD be the outer diameter of the annulus, CG the inner, E the centre, and AC the thickness of the ring.

On AC describe the semi-circle ABC: then, if ABC be supposed to be set or turned perpendicular to the plane of the paper, it will represent half the section of the ring. From E, with the radius EA, describe the semi-circle AFD; and, from the same centre, E, with the radius EC, describe the semi-circle CHG; then AFD is the outer circumference, and CHG the inner circumference; and, consequently, AFDGHCA, is the section of the ring, perpendicular to the fixed axis; and the section ABC of the solid itself is perpendicular to the section AFDGHC.

To find the form of any board; divide the circumference ABC of the semi-circle into such a number of equal parts as the boards or planks out of which they are to be cut will admit.

Let *ab* be the distance between two adjacent points; through the centre E draw HI, perpendicular to AD; and through the points *a* and *b*, draw the straight line *ac*, meeting HI in the point *c*: from *c*, with the radius *ca*, describe an arc; and from the same centre, *c*, with the radius *cb*, describe another arc, and enclose the space by a radiating line at each end; and the figure bounded by the two arcs, and the radiating lines, will be the form of the board required.

In the same manner the form of every remaining board may be found.

It is obvious that, as common boards are not more than nine or ten inches in breadth, the boards formed for the covering cannot be very long; or otherwise they must be very narrow, which will produce much waste.

To cover an ellipsoidal Dome, the major axis of the generating ellipse being the fixed axis (*pl.* XV, *fig.* 3).

Let ABC be the section through the fixed axis, or generating ellipse, which will also be the vertical section of such a solid.

Produce the fixed axis AC to I, and divide the curve ABC into such a number of equal parts that each may be equal to the proper width of a board. Then, as before, draw a straight line through two adjacent points *a* and *b*, to meet the line AI in *c*; then, with the radii *ca* and *cb*, describe arcs, and terminate the board at its proper length.

No. 2, (*fig.* 3,) is an horizontal section of the dome, exhibiting the plan of the boarding.

# COVERINGS OF CIRCULAR ROOFS.

Fig 1

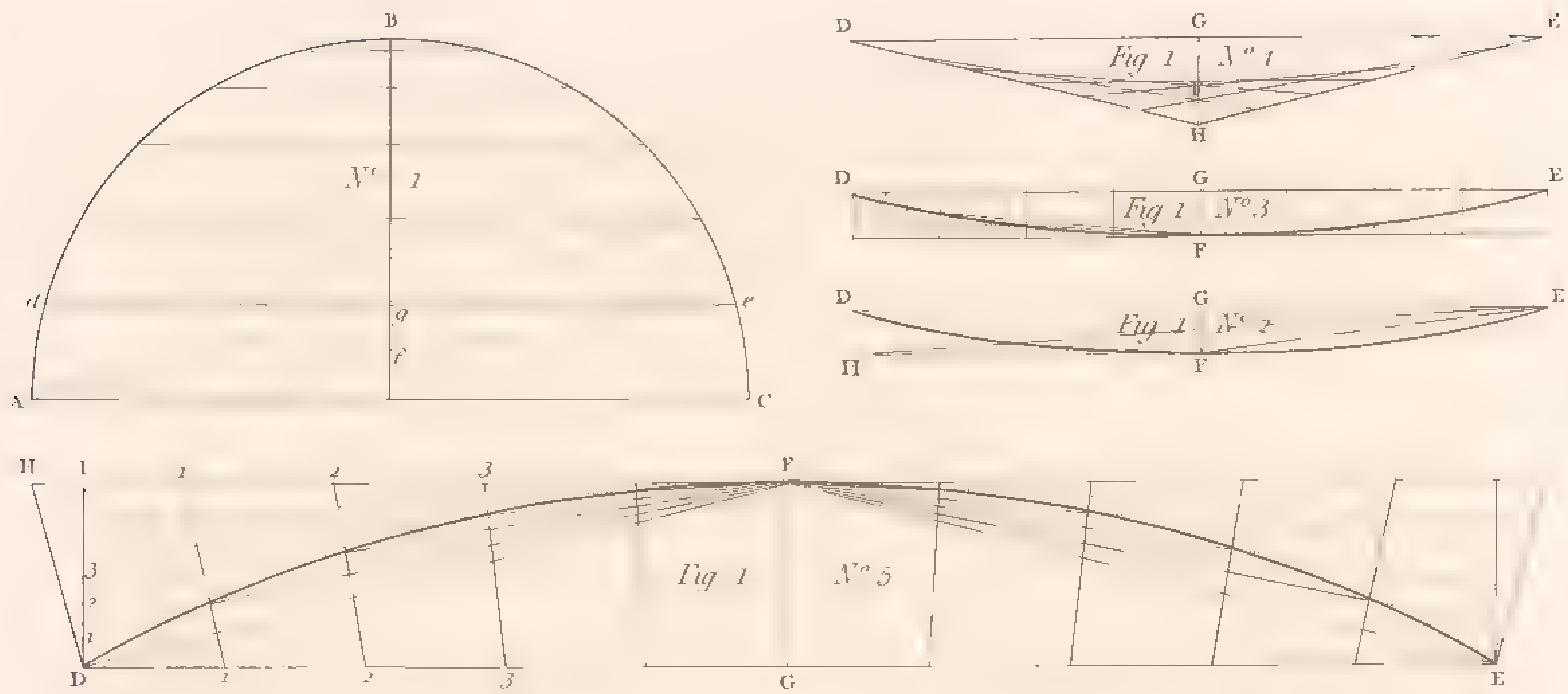


Fig 2.

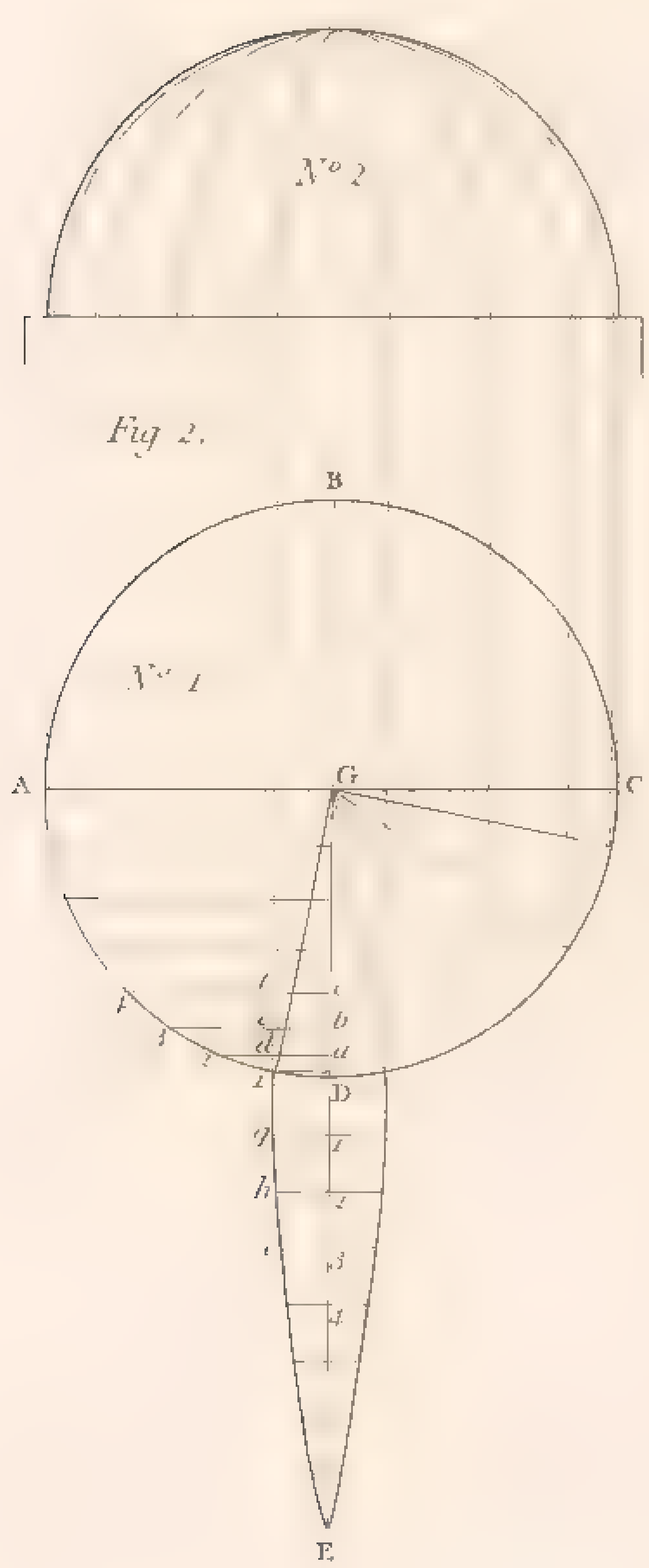


Fig 3

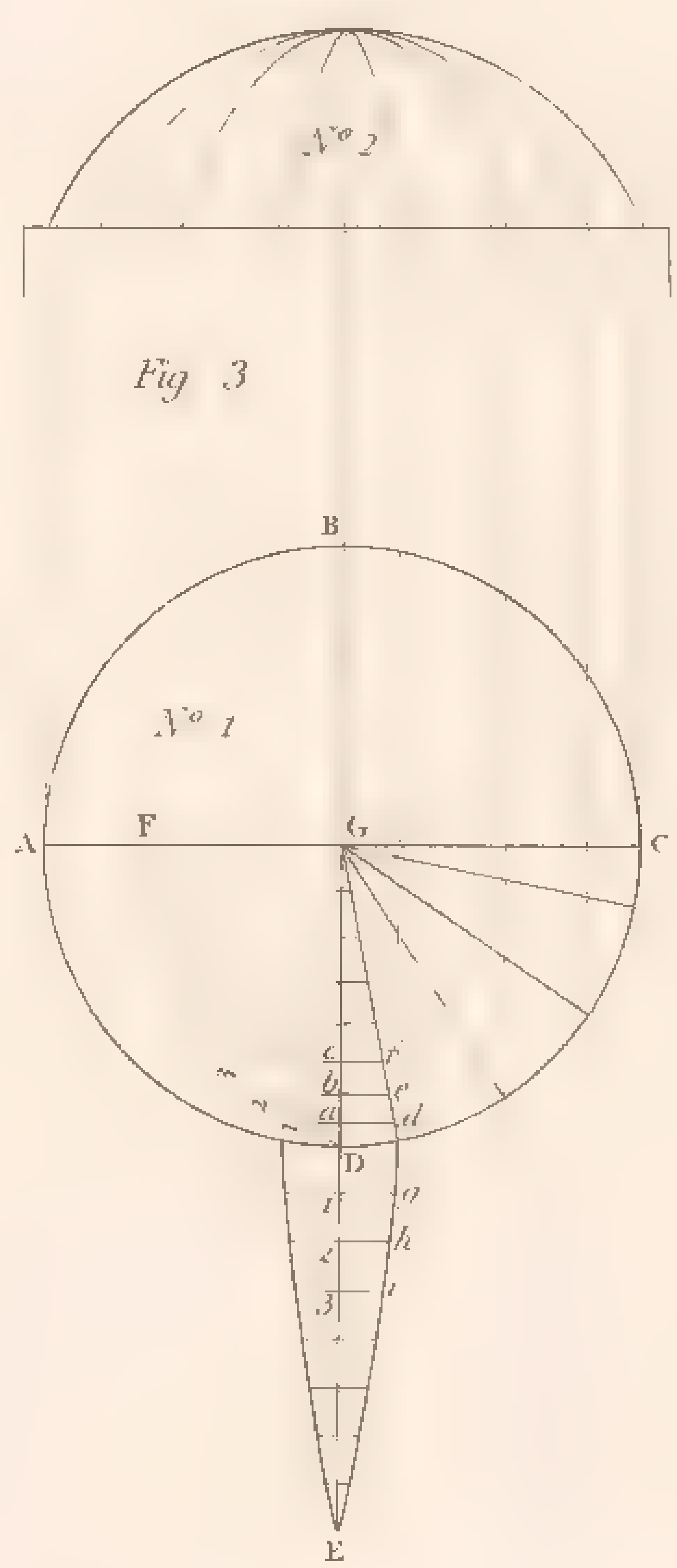
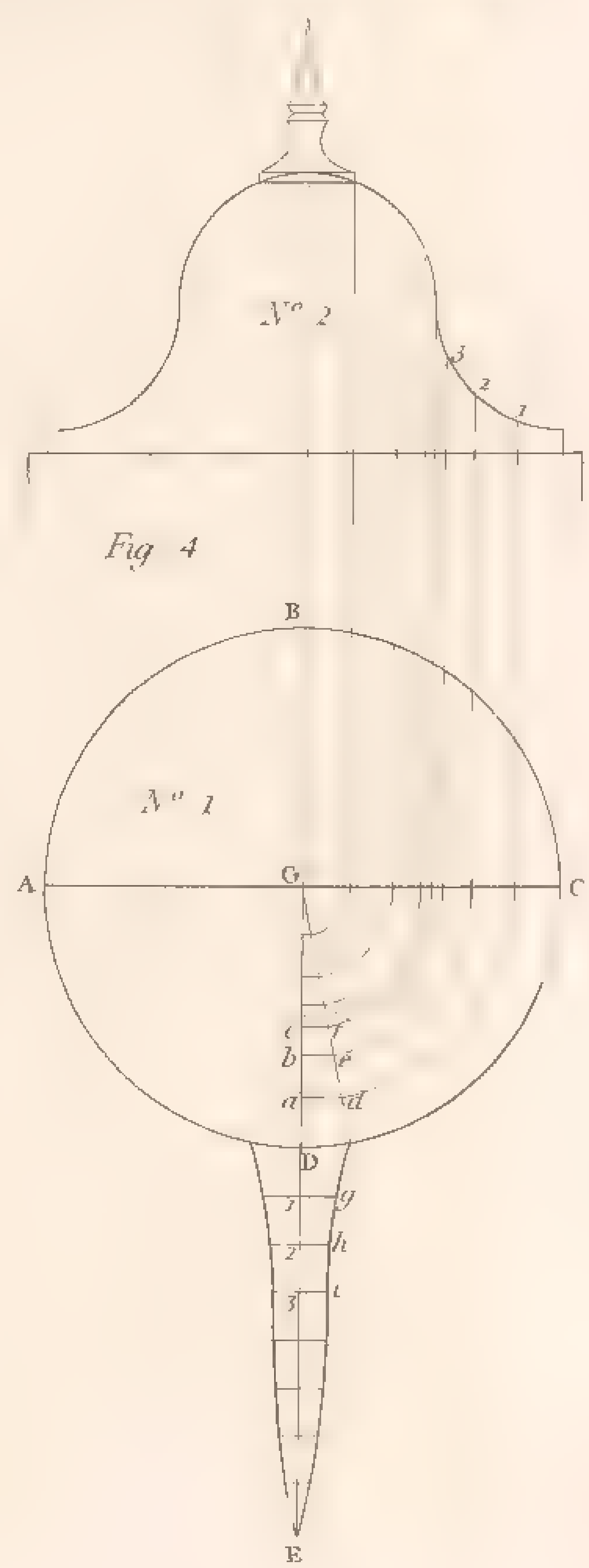


Fig 4



Drawn by P. Nicholson.

Engraved by W. Symns.

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*Figure* 4 is a section of a circular roof. The principle of covering it with boards bent horizontally, is exactly the same as in the preceding examples.

It is now necessary only to explain ONE GENERAL PRINCIPLE, which extends to the whole of these round solids. The planes which contain the conic frustums are all perpendicular to the fixed axis, which is represented by HC, in all the figures. Produce *ab*, to meet the fixed axis HI in *c*; then, with the radius *ca*, describe an arc; and, with the radius *cb*, describe another arc, which two arcs will form the edges of the boards; the ends are formed by radiating lines. Now, which ever figure we inspect, we shall find this rule to apply.

As the boards approach nearer to the revolving axis, they may be made either wider or longer; but, as the boards approach nearer to the fixed axis, the waste of stuff will be greater, and, consequently, the boards must be shorter.

When the boards come very near to the bottom of the dome, the centres for describing the edges of the boards will be too remote for the length of a rod to be used as a radius. In this case we must have recourse to the following method. Let ABC, (*fig.* 1, *pl.* XVI,) be the section of the dome, as before, and let *e* be the point in the middle of the breadth of a board: draw *ed* parallel to AC, the base of the section, cutting the axis of the dome in *g*, and join A*e*, cutting the axis in *f*. Then, by *problem* 10, *page* 64, describe the segment of a circle, through the three points *d*, *f*, *e*, and this will give the curve of the edge of the board, as required.

*Figure* 1, No. 2, exhibits the manner of using the instrument. Thus, suppose we make DE equal to *de*, No. 1: Bisect DE in G, and draw GF, perpendicular to DE, and make GF equal to *gf*, No. 1. Draw FH parallel to DE, and make FH equal to FE, and join EH; then cut a piece of board into the form of the triangle HFE; then let HFE be that triangle; then move the vertex F from F to E, keeping the leg FE upon the point E; and the leg F, and the angular point F of the piece, so cut, will describe the curve, or perhaps as much of it as may be wanted.

It must be here observed that the line described is the middle of the board; but, if the breadth of the board is properly set off at each end, on each side of

the middle, we shall be able to describe the arc with the same triangle; or, if the concave edge of the board is hollowed out, the convex edge will be found by gauging the board off to its breadth.

As all the conic sections approach nearer and nearer to circles, as they are taken nearer to the vertex; a parabola, whose abscissa is small, compared to its double ordinate, will have its curvature nearly uniform, and will, consequently, coincide very nearly with the segment of a circle; and, as this curve is easily described, we shall here employ it instead of a circular arc, as in Nos. 3 and 4.

Draw the chord DE, as before, and bisect it in G. Draw GF perpendicular to DE, and make GF equal to *g f*, in No. 1: so far the construction of the diagrams, Nos. 3 and 4, are the same; but, in what follows, they are different: we shall, therefore, take each of them separately, and first No. 3.

Divide each half, DG, GE, into the same number of equal parts; and, through the points of division, draw lines perpendicular to DE; also, from the points D and E, at the extremities, draw perpendiculars; and make each of these perpendiculars equal to GF; then divide each into as many equal parts as DG or GE is divided into, and, through the points of division, draw lines to F, intersecting the perpendiculars; and, through the points of intersection, draw a curve, on each side of the middle point F, and this will be the form of the edge of the board, nearly.

In No. 4, make FH equal to *g f*, No. 1, and join DH and HE. Then divide DH and HE, each into the same number of equal parts; then, through the corresponding points of division, draw straight lines, and the intersection of all the lines will form the curve sufficiently near for the purpose. The lines thus drawn being tangents to the parabolic curve.

The arc of a circle may, however, be accurately drawn through points, by the following method:

Let DE, (*fig.* 1, No. 5,) be the chord of the segment, and GF the versed sine. Through F draw HF, parallel to DE; join DF, and draw DH perpendicular to DF. Divide DG and HF each into the same number of equal parts, as five, in this example; draw DI perpendicular to DG, meeting HF in

in I; and divide DI into the same number of parts as DG: *viz.* five. Join the points of division in DG to those in HF, and also through the points of division in DI draw straight lines to the point F, cutting the former straight lines, drawn through the points of division in the lines DG and HF: then trace a curve from the point D, and through the points of intersection to F, and we shall have one half of the circular arc. The other half is found in the same manner, as is obvious from inspection of the figure.

THE PRECEDING METHOD of covering round solids requires all the boards to be of different curvatures, and continually quicker as they approach nearer to the crown; but, by the following method of covering a dome, with the joints in vertical planes, when the form of one of the moulds is obtained, this form will serve for moulding the whole solid. The waste of stuff in this case is not less than in the other.

The method which we are about to explain is not only useful in the formation of the boards of a DOME, but in the covering of NICHES.

In *figures* 2, 3, 4, (*pl.* XVI,) No. 1 is the plan, and No. 2 the elevation; the contour of the latter being a vertical section passing through the axis. *Figure* 2 represents a dome, whose contour is a semi-circle; *figure* 3 represents a segmental dome; *figure* 4 represents a round body, of which the vertical section is an *ogee*, or curve of contrary flexure.

Through the centre of the plan, G, draw the diameter, AC; and the diameter BD, at right angles to AC; and produce BD to E. Let BD, *figures* 2 and 3, be the base of a semi-section of the dome: on BD apply the semi-section CFD; and as the dome, represented by *figure* 2, is semi-circular, the point F will coincide with the point A in the circumference of the plan. In *figures* 2 and 3 divide the curve FD, of the rib, into any number of equal parts, and extend the curve DF upon the straight line DE, from D to E; that is, make the straight line DE equal in length to the curve DF. Through the points of division, in the curve DA, draw lines perpendicular to DG, cutting it at the points *a*, *b*, *c*: then, extending the parts of the arc between the points of division upon the line DE, from D to 1, from 1 to 2, from 2 to 3, &c.: make

D*d* equal to half the breadth of a board, and join *d*G; produce the lines 1*a*, 2*b*, 3*c*, &c., drawn through the curve DF, to meet the line *d*G, in the points *d*, *e*, *f*, &c. Through the points 1, 2, 3, &c., in DE, draw perpendiculars 1*g*, 2*h*, 3*i*, &c.: make 1*g*, 2*h*, 3*i*, &c., respectively equal to *ad*, *be*, *cf*, &c.; and, through the points *d*, *g*, *h*, *i*, &c., E, draw a curve, which will form one edge of the board. The other edge, being similar, we have only to describe a curve equal and similar, so as to have all its ordinates respectively equal from the same straight line DE.

In *fig*. 4, the form of the mould for the boards is found in a similar manner, except that the curve DE is one side of the elevation, No. 2: Lines are drawn from the points of division in DE perpendicular to the diameter AC, which is parallel to the base of No. 2; and the points of division are transferred from the radius GC, to the radius GD, which is the base of the section. The remaining part of the process is the same as in *figures* 1 and 2.

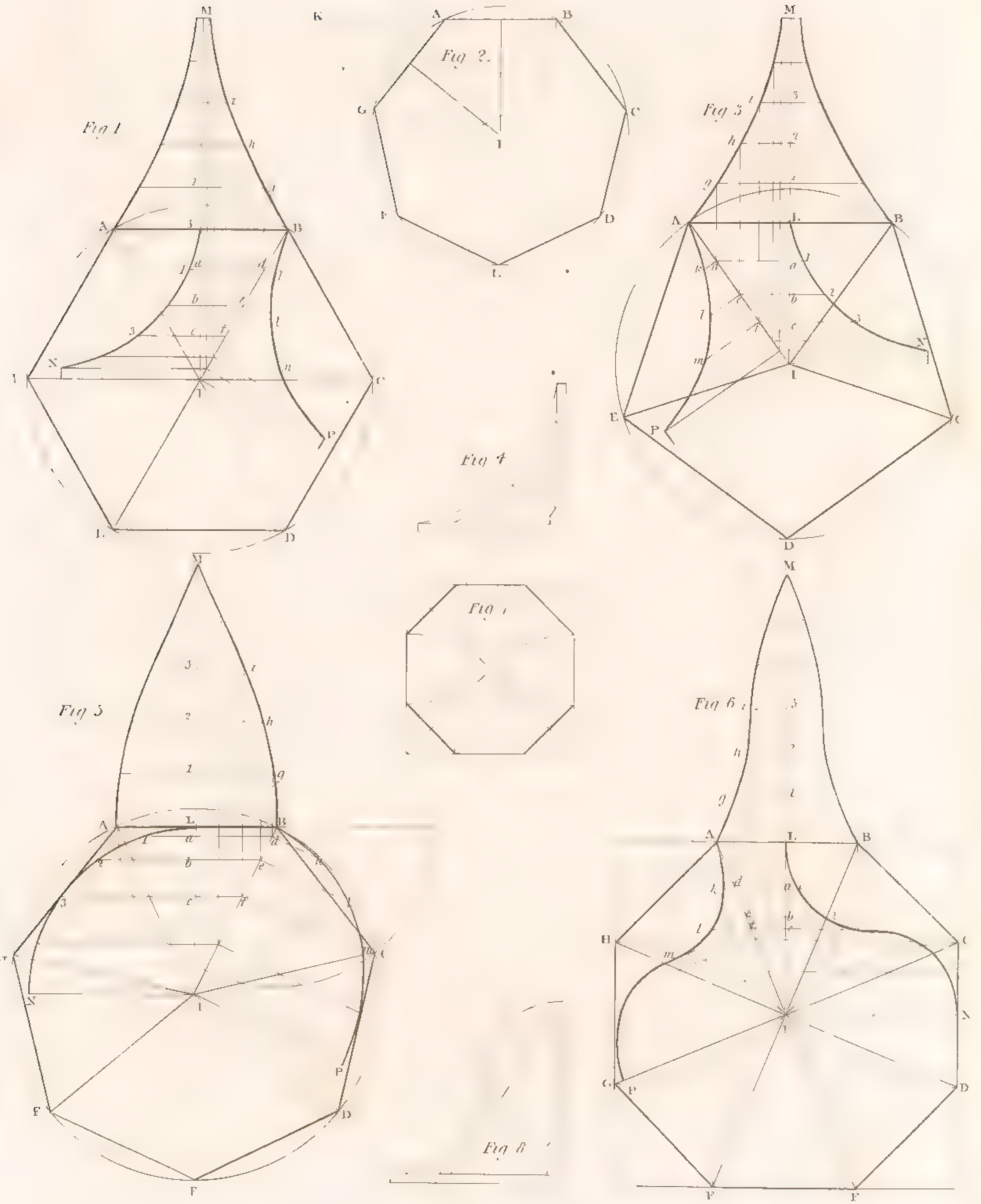
In *figure* 2, the curved edge of the board is a symmetrical figure of the sines; the curves of the mould, *fig*. 3, is a smaller portion of the figure of the same curve: and, in *fig*. 4, the mould is a curve of contrary flexure; and if the curve DE be composed of two arcs of circles, the curve of the edges of the mould for the boards will still be compounded of the figure of the sines set on contrary sides; and, if the curve DE be compounded of two elliptic segments, the edges of the mould for the formation of the boards will still be of the same species of curve: *viz*. the figure of the sines.

This figure occurs very frequently in the geometry of building.

## COVERINGS OF POLYGONAL ROOFS.

The plans of these roofs are here supposed to be regular polygons, and all the sections parallel to the base, similar to the base, and, consequently, similar to one another. They are made of prismatic solids, meeting each other in planes perpendicular to the plane of the base; and these mitre-planes meet each other in one common axis, which passes through the centre of each polygon.

# POLYGONAL ROOFS.

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In *pl.* XVII, *fig.* 1, the plan is denoted by the letters ABCDEFA. Then the centre of the polygon being the point I, draw the lines AI, BI, CI, &c. Bisect any of the sides, as AB, in the point L, and draw LI; then LI is perpendicular to AB.

Produce the line IL to M, and let ILN be the section applied upon IL. In the curve LN take any number of points 1, 2, 3, at equal distances, and transfer these distances to the line LM, so that LM may be equal to the arc LN. Through the points 1, 2, 3, &c. in LM, draw lines 1*g*, 2*h*, 3*i*, &c. parallel to AB; and through the points 1, 2, 3, &c., in the arc LN, draw lines 1*d*, 2*e*, 3*f*, &c., also parallel to AB, cutting LI at the points *a*, *b*, *c*, &c., and BI at the points *d*, *e*, *f*, &c.: Make 1*g*, equal to *ad*, 2*h* equal to *be*, 3*i* equal to *cf*, &c. Through the points *g*, *h*, *i*, &c., draw a curve, which will be the edge of the joint over the mitre.

To find the angle-rib, through the points *d*, *e*, *f*, &c., draw *dk*, *el*, *fm*, &c. perpendicular to BI. Make *dk*, *el*, *fm*, &c., respectively equal to *a*1, *b*2, *c*3, &c. Through the points *k*, *l*, *m*, &c., draw a curve, which will be the edge of the angle-rib, as required.

*Figure* 2 shows the manner of describing a polygon, to any given number of sides. Thus suppose, upon the side AB, it were required to describe a *heptagon*. Produce BA to K, and, with the radius AB, describe a semi-circle, BGK, of which the diameter is BK; divide the arc BK into seven equal parts, and through the second division, G, draw AG; then BA and AG are two adjacent sides of the heptagon. Bisect each of the sides AG and AB by a perpendicular, meeting each other at I. Then I is the centre of a circle that will contain either of the sides AB or AG seven times. The equal chords, being inscribed in the remaining part of the circle, will complete the polygon as required. In this manner we may describe a polygon of any given number of sides whatever; by producing the given side, and describing a semi-circle on that side, and the part produced, and dividing the arc into as many equal parts as the polygon is to contain sides; then, drawing a line from the centre, through the second point of division, will form two adjacent sides of that polygon. The remaining part of the process is to be completed as before.

*Figure* 3, (*pl.* XVII,) shows the manner of finding the covering of a roof, when the plan is a regular pentagon.

*Figure* 4, exhibits the method of framing the ribs for such sorts of roofs.

*Figure* 5, shows the manner of describing the covering and ribs of a domical roof.

*Figure* 6, shows the manner of describing the covering and ribs of a roof whose vertical section is a figure of contrary curvature.

*Figure* 7, shows the method of describing a regular octagon from a given square. Thus, draw the diagonals; then, with half the diagonal, as a radius, and from each of the four angular points of the square, describe a quadrant or arc; join the two adjacent points of intersection, in each two adjacent sides of the square, and you have the octagon required.

*Figure* 8, exhibits the manner of forming one of the ribs for the ogee roof, or that of contrary curvature.

The method of finding the coverings and ribs of *figures* 3, 5, and 6, is the very same as that described in *figure* 1.

Such forms of roofs most frequently occur in temples or garden-buildings.

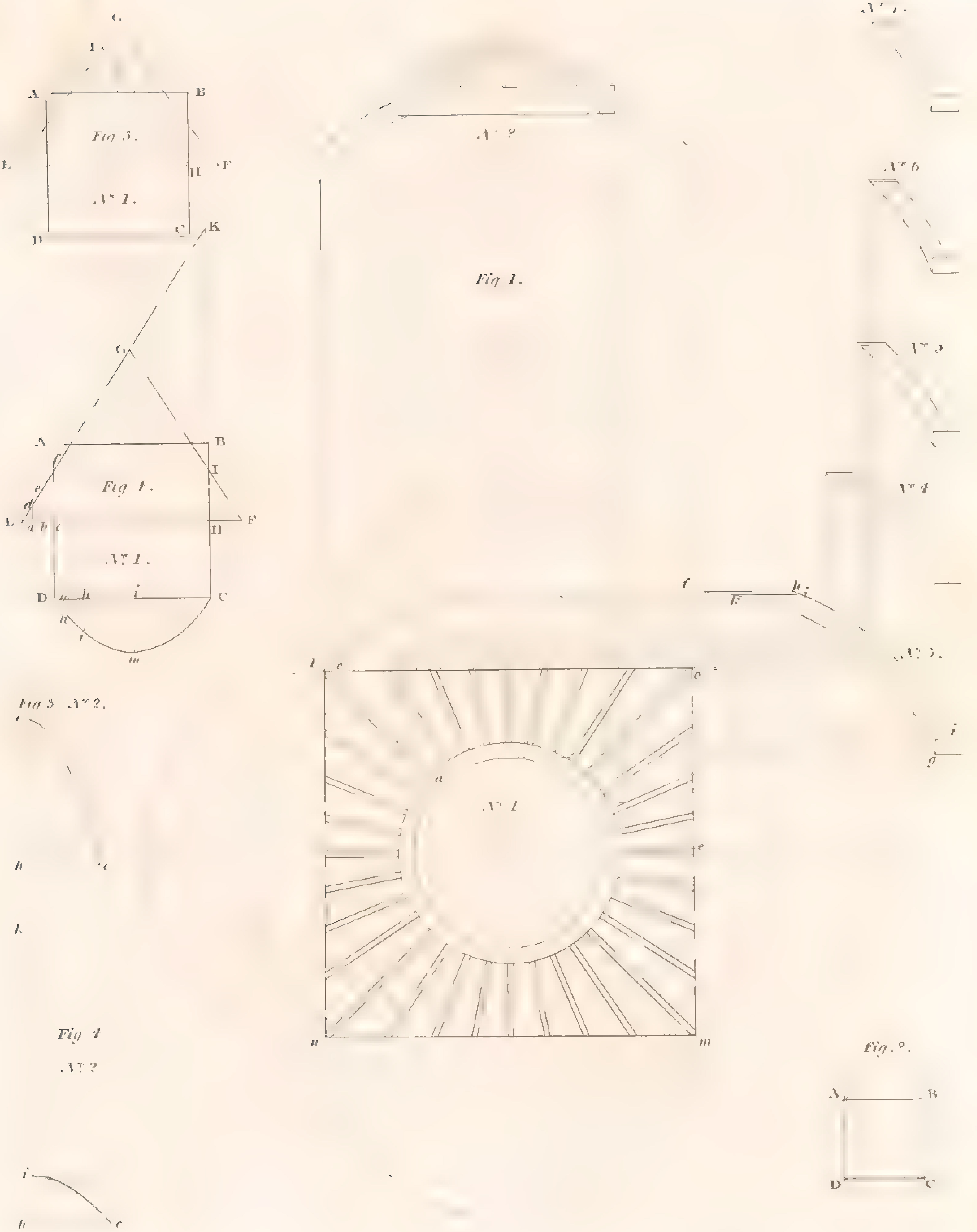
Polygonal Roofs and Circular Domes are of the same nature; as a dome cannot be covered upon any other principle than that of a polygon having a finite number of sides.

## PENDENTIVE BRACKETING.

PENDENTIVE BRACKETING occurs when certain portions of a concave surface are carried from the sides of a rectangular or polygonal room to a level ceiling or cornice. The parts thus introduced, between the walls and the ceiling, are called Pendentives.

Pendentives are either spherical, spheroidal, or conical. The figure in the walls, from which they spring, depends entirely upon the following principles:

# PENDENTIVE BRACKETING.

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It is well known that, if a sphere be cut by a plane, the section will be a *circle;* and, if a hemisphere be cut by a plane perpendicular to its base, the section will be a *semi-circle.* If a right cone be cut by a plane, perpendicular to its base, the section will be an *hyperbola;* and, generally, if any conoid, formed by the revolution of a conic section about its axis, be cut by a plane perpendicular to its base, the section will always be similar to the section of the solid passing through the axis; and every two sections of a conoid, cut by a plane perpendicular to the base, at an equal distance from the axis, are equal and similar figures. Therefore if, on the base of a hemisphere, we inscribe a square within the containing circle, and cut the solid by planes perpendicular to the base, through each of the four sides of the square, the four sections will represent the four portions of each wall, and the arcs will represent the springing lines for the spherical surfaces.

On *pl.* XVIII, *fig.* 1, No. 1 is the plan of a room, with the ribs which form the pendentive ceiling; the semi-circles on the sides are supposed to turn up perpendicular to the plan *bnmo,* which will form the terminations of the four walls; No. 2 is the elevation.

Numbers 3, 4, 5, 6, and 7, exhibit the ribs for one-eighth part of the whole; and, as these ribs are all in planes passing through the axis, they are all great circles of a sphere, of which the diagonals of the square is a diameter; therefore, though the ribs are shorter in the middle of each side, and increased towards the angles, they are all described with the same radius, which is half the diagonal of that square. The whole of the scheme may be formed in paste-board. Thus, in *figure* 2, let ABCD be the plan; on each of the sides, AB, BC, CD, DA, describe a semi-circle; then let each semi-circle be turned round its respective diameter until its plane becomes perpendicular to the plane ABCD; then the sides, thus turned up, will represent the sections of the sphere, and ABCD the base of the solid; then the surface extending between the semi-circular arcs is entirely spherical.

In *figure* 3, the pendentives are supposed to be placed on a conic surface, and the sides of the square not perpendicular, but equally inclined on every side, approaching nearer together as they ascend.

Thus, let ABCD be the plan, and the circumscribing circle the base of the cone, and EGF a section of the cone through its axis. Then, if the inclination of each of these four planes be the angle EHI, making HI parallel to FG, then the conic section is a parabola, and may be drawn as shown at *fig.* 3, No. 2, and as described in the Practical Geometry of this Work.

*Figure* 4, (*pl.* XVIII,) shows the method of describing the springing lines, when the sides are perpendicular to the plane ABCD. From the centre of the square, and through the angular points, describe the circle ABCD, and draw the diameter EF, parallel to any one of the sides, cutting AD and BC in *c* and H. In E*c* take any number of points, *a*, *b*, &c., and draw *ad*, *be*, *cf*, perpendicular to EF, cutting the side EG, of the section of the cone, in the points *d*, *e*, *f*, &c. From the centre of the plan describe the arcs *ci*, *bh*, *ag*, cutting the side DC in *g* and *h*, and the arc *ci* touching it in *i*. Perpendicular to DC, draw *im*, *kl*, *gh*, and make *im*, *kl*, *gh*, respectively equal to *cf*, *be*, *ad*. Then, upon the given base, DC, describe the symmetrical figure, D*mc*, which will form the springing line, in order to set the ribs upon the wall.

As this figure is an hyperbola, it may be described, independently of tracing it from the plan, thus: In *fig.* 4, No. 1, draw HK perpendicular to EF, cutting the side GF of the cone in I, and meeting the other side EG, produced in K, and IK will be the axis, IH the abscissa, and HC or HB the ordinate: then describe an hyperbola, *fig.* 4, No. 2, which has its axis, abscissa, and ordinate, respectively equal to IK, IH, HB, or HC.

*Figure* 1, (*pl.* XIX,) is the elevation of conical pendentives. In order to form the conic surface, the figure of an hyperbola must be described upon each side of the room. The figure in the plate exhibits two sides of the room. In this diagram *aglib* represents the springing line on one side of the room, and *bhc* that on the other side; the former agreeable to the straight line AB on the plan, No. 1, and the latter agreeable to the straight line BC on that plan.

*Figure* 2 is a section and angular elevation of spherical pendentives; the plan being exhibited by No. 1.

# PENDENTIVES.

Fig. 1

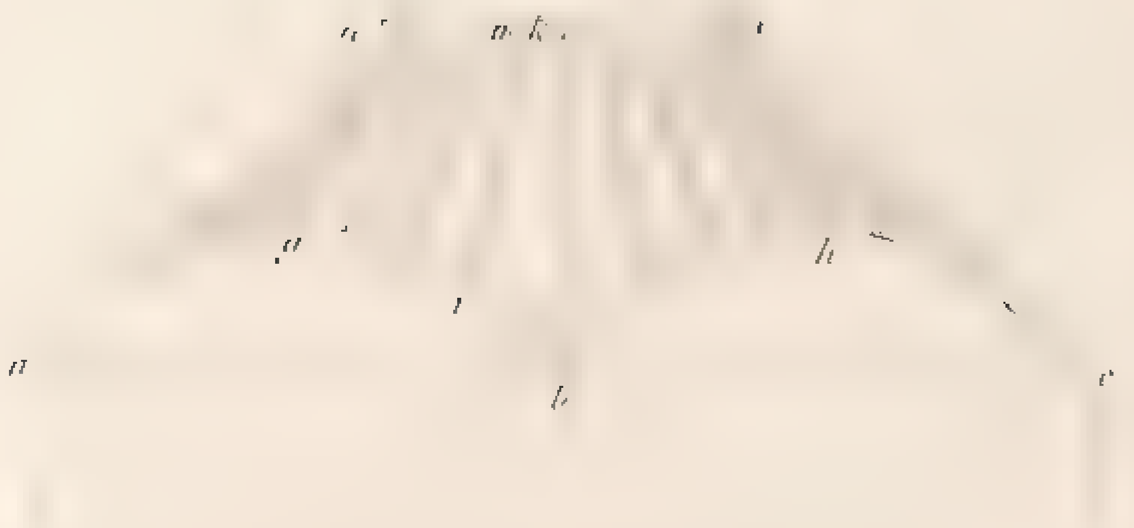

Fig. 2

Fig. 1. Nº 1

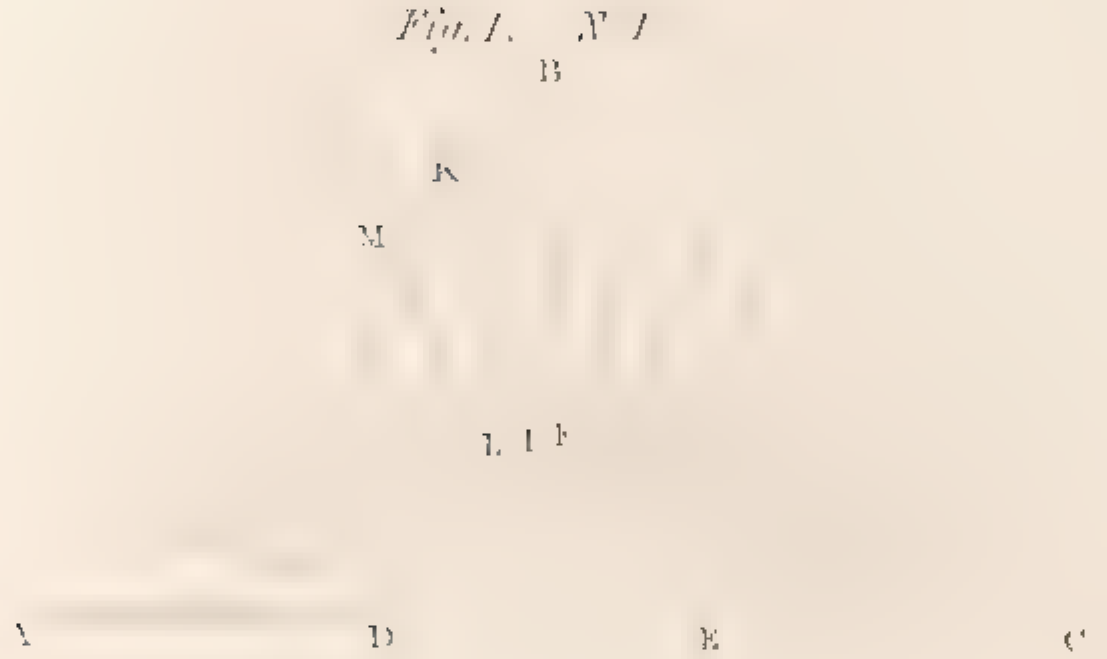

Fig. 2. Nº 1

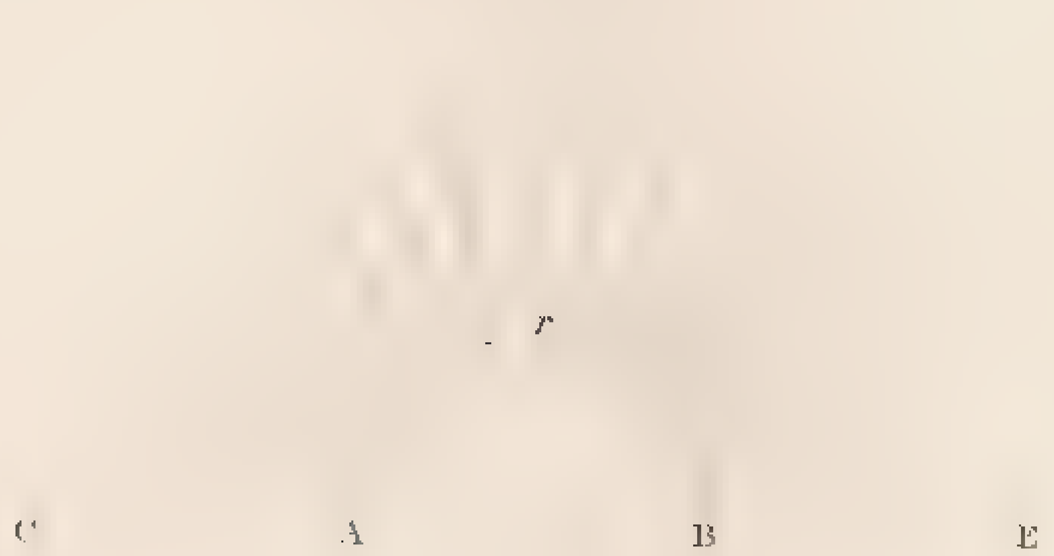

Fig. 3

Fig. 4.

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*Figure* 3 shows the method of drawing the springing lines on the walls; the plan and the rib over the diagonal of the plan being given agreeably to the elevation, *fig*. 2. Here the plan is the square ABCD, and the rib over the diagonal of the square is DEFB.

From the centre V, with a radius equal to half the side of the square, describe the arc *g*PG, which will touch the two sides DC, CB, of the square, at P and G, which are each in the middle of these sides; and let the arc, thus described, cut the line BD at *g*. Draw *g x*, perpendicular to DB, cutting the curve DE at *h*.

Let QG, RI, SL, TN, UC, be the seats of the ribs for one-eighth part of the whole; and since these are similar to those in every other eighth part, their formation will be sufficient for the whole of the ribs; since there will be four ribs, for every one of those in the eighth part, exactly alike, so that each rib becomes a mould for three more. The plans QG, RI, SL, TN, UC, divide any arc described from the centre, V, into four equal parts, and terminate upon the side BC of the square, in the points G, I, L, N. Draw GH, IK, LM, NO, perpendicular to BC; also draw *iy*, *lz*, *n*&, perpendicular to DB, cutting the under edge DE of the rib over the diagonal in the points *k*, *m*, *o*. Make GH, IK, LM, NO, each respectively equal to *g h*, *i k*, *lm*, *no*; then the curve HKMOC being drawn, will be half the springing line over BC; the other half, being made similar, will be the whole of the springing line. This springing line will serve as a mould for drawing the springing lines upon each of the four walls. As all the ribs are portions of a circle of the same radius, that is, they will have the same curvature as the edge DE of the rib which stands upon the diagonal; the portion of each rib will be D*h*, D*k*, D*m*, D*o*, cut by the lines *hx*, *ky*, *mz*, *o*&.

*Figure* 4 shows the springing lines for each wall, agreeably to the plan and elevation, *fig*. 1. The method is exactly the same as that described for *fig*. 3; and thus any farther description will not be necessary.

## PURLINS IN CIRCULAR ROOFS.

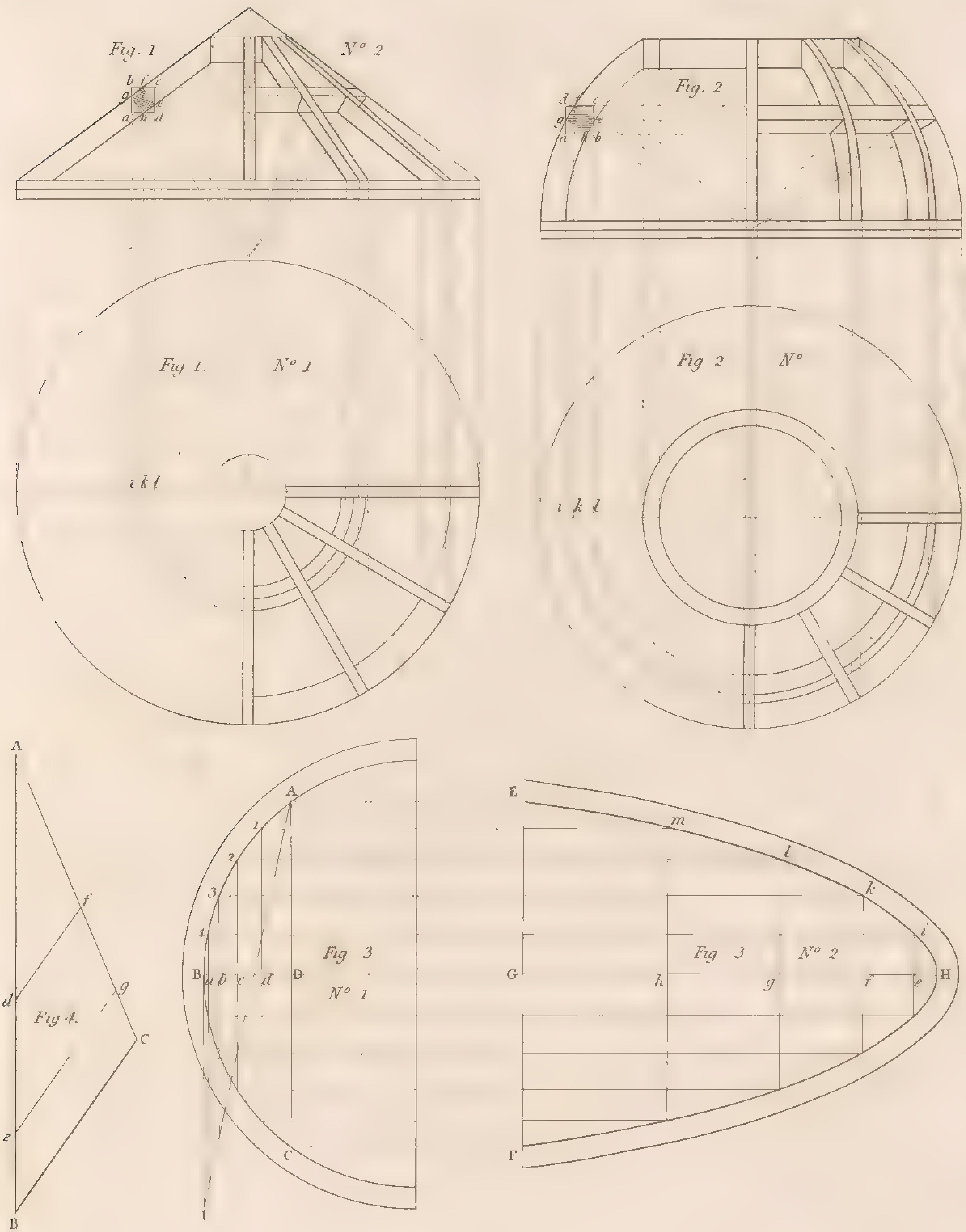
In *plate* XX, *figures* 1 and 2, are the orthographical projections of a conical and domical roof; No. 1 being the plan, and No. 2 the elevation.

The first thing to be done is, to draw the contour both of the plan and elevation. In the one extreme rafter let *gfeh* be the section of the purlin. Round the angular points *g, f, e, h,* describe the square *abcd*: then will *fb, fc, bg, ce, ag, de, ha, hd,* be the parts that are to be guaged off, after having been squared to the circular plan.

In church-building, it frequently happens that the windows are either carried entirely across the gallery-floors, or their heads considerably above the ceilings of those floors; in either case, the light is so much intercepted, that it is necessary to hollow out the ceiling, in order to obtain a sufficient quantity of light. This may be done in a very elegant manner, when the head of the window is circular. For, if we conceive an oblique cylinder, forming the head of the window, in the segment of the circle, which is the base of the cylinder to be inserted, and to displace a portion of the ceiling, that portion of the ceiling must therefore be a cylindric surface, and the hollow required to be formed. Now, it is evident that, if ribs are formed to curves of the same circle as the head of the window, and set in vertical planes, or parallel to the surfaces of the windows, and properly ranged, they will form the cylindric surface required.

Let the segment ABC, *fig.* 3, (No. 1, *pl.* XX,) be the head of the window, and let the chord AC be the ceiling-line. Divide the arc into two equal parts, AB, BC, and divide AB into any number of equal parts; as here into five. Through the points of division, draw lines parallel to AC. In No. 2, suppose GH to be the length intended for the curb. Suppose now that planes, parallel to the axis of the cylinder, in No. 1, pass through the chord AC, and through the points 1, 2, 3, 4, all parallel to each other, and to be cut by the plane of the ceiling; the sections of these planes with the ceiling will divide

# PURLINS IN CIRCULAR ROOFS.

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# DOMES.

*Fig. 1. No. 1.*

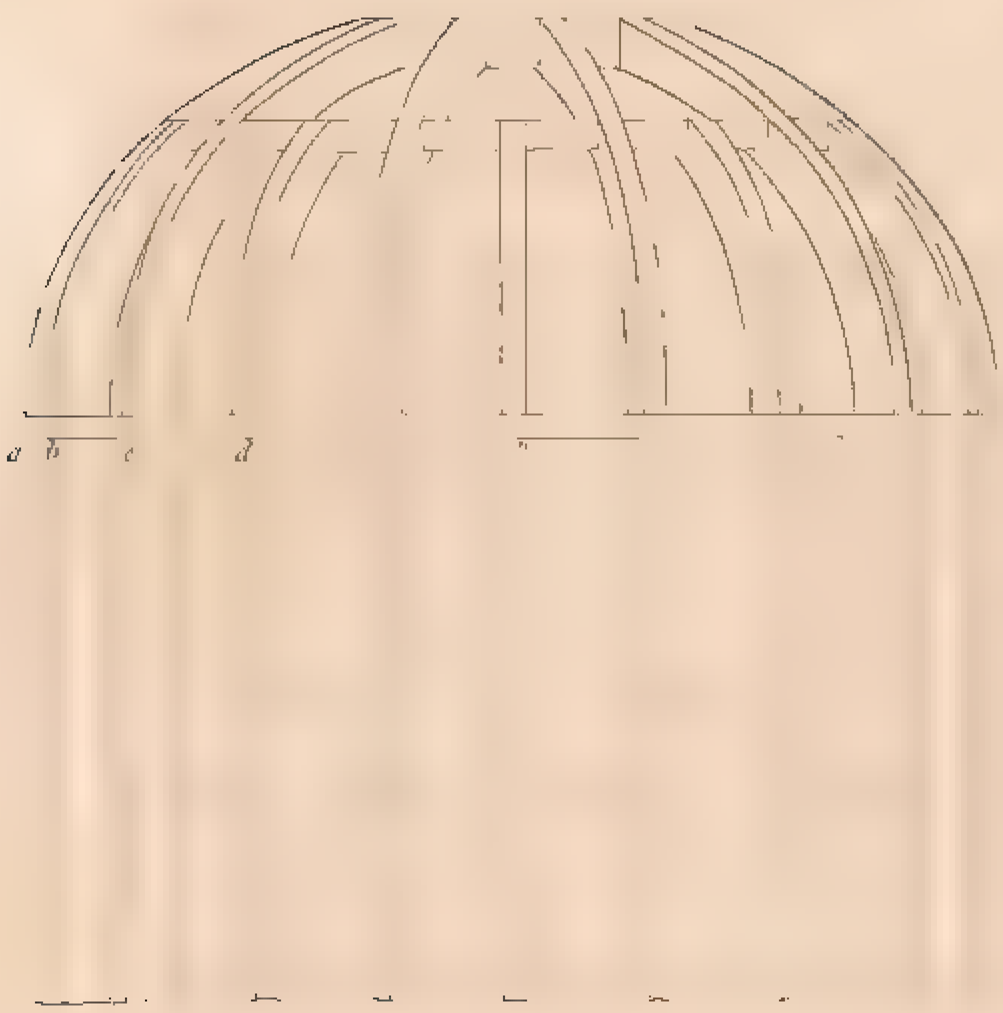



*Fig. 2. No. 1.*

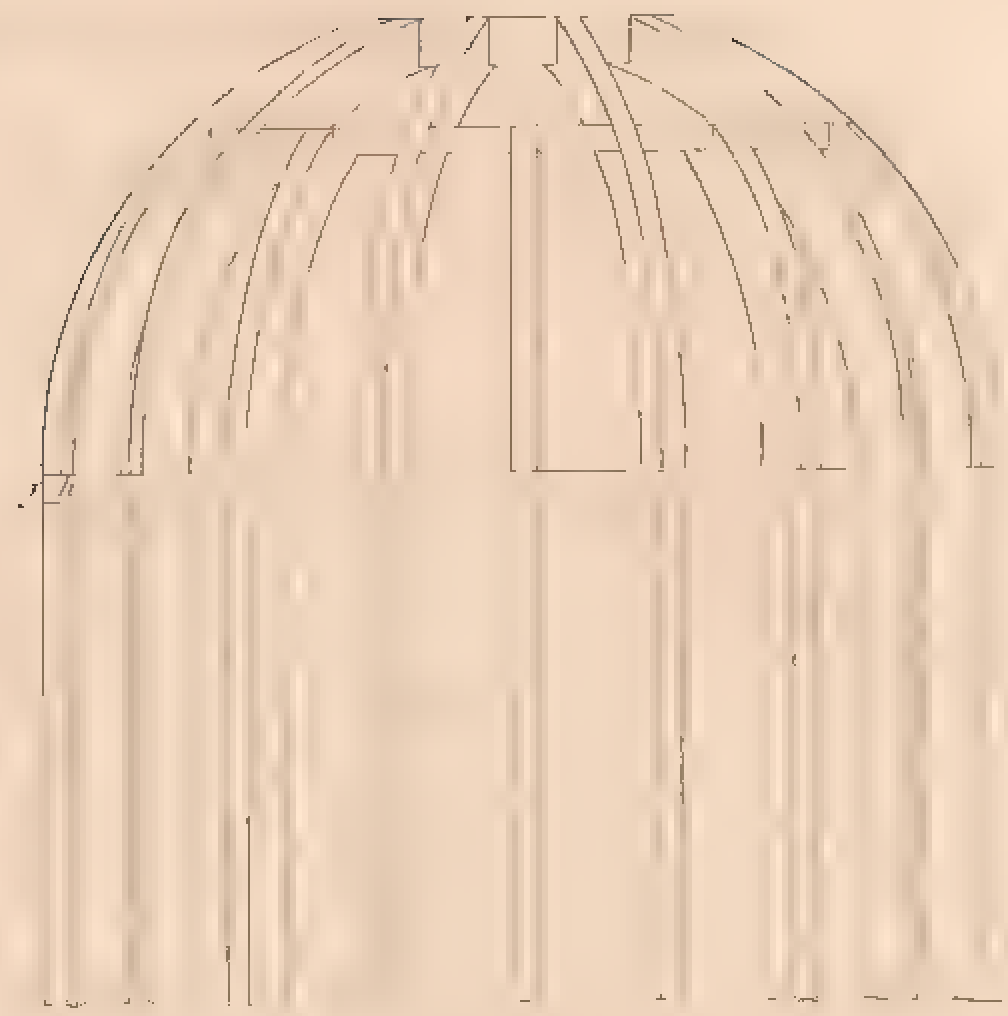


*Fig. 1. No. 2.*

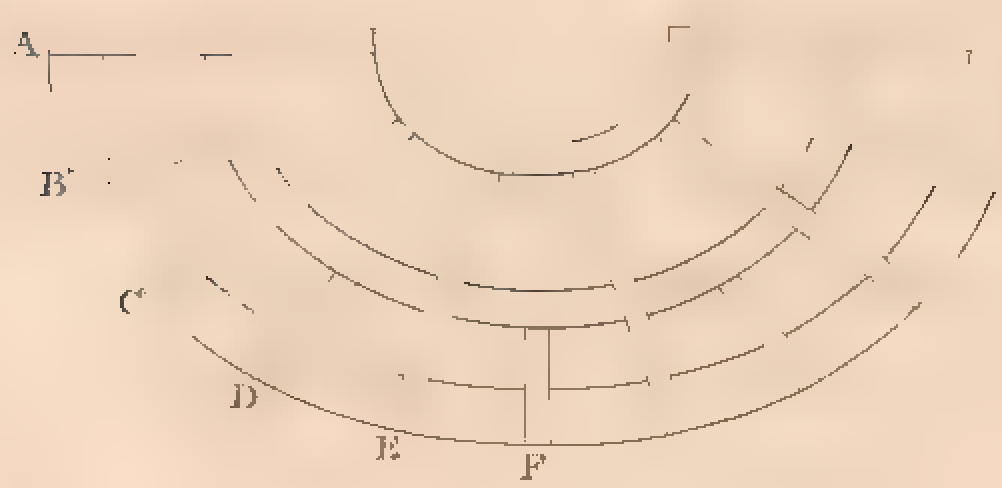



*Fig. 2. No. 2.*

G

H

*Fig. 1. No. 3.*

A

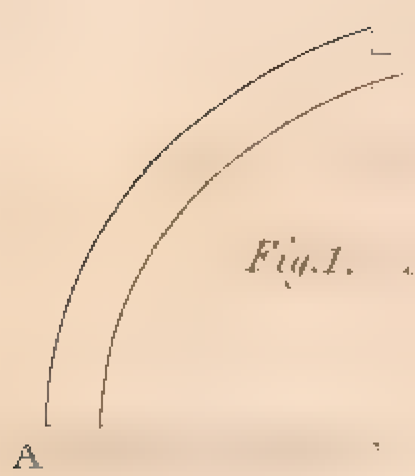


*Fig. 1. No. 4.*

B

*Fig. 2. No. 3.*

G

*Fig. 2. No. 4.*

H

*Fig. 1. No. 5.*

C

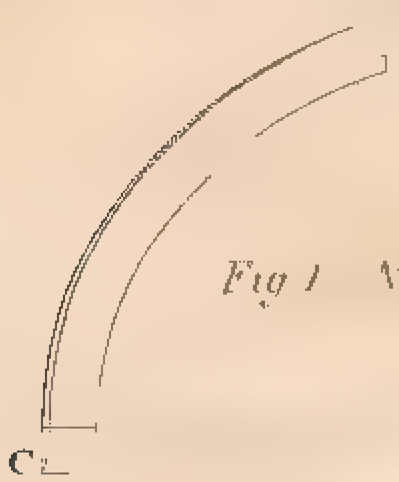


*Fig. 1. No. 6.*

D

*Fig. 1. No. 7.*

E

*Fig. 1. No. 8.*

F

*Drawn by M.A. Nicholson*

*Engraved by W. Symns.*

*London, Published by Thos. Kelly 17 Paternoster Row November 1.1822.*

the ceiling into parts, which will have the same ratio as the parts B*a*, *ab*, *bc*, *cd*, *d*D. Hence, if we take GH, No. 2, as a radius, and in No. 1, from A, describe an arc at I, cutting the line BI parallel to AC; then the lines passing through the points A, 1, 2, 3, 4, parallel to AC, will divide AI in the same proportion as the planes, parallel to the axis, will divide the ceiling line; therefore mark out the divisions, thus cut in the line AI, upon GH, No. 2, and let *e*, *f*, *g*, *h*, be these divisions. Through the points *e*, *f*, *g*, *h*, G, draw the perpendiculars *ei*, *fk*, *gl*, *hm*, GE. Make *ai*, *fk*, *gl*, *hm*, No. 2, respectively equal to *a*4, *b*3, *c*2, *d*1, DA, No. 1; then make the figure symmetrical upon the base FE; then the curve EHF is the inside of the curb. As to the outside of the curb, it may be of any form whatever. The segment, whose chord is AC, is the form of the rib to be set upon EF, and the segment which has 2*n* for its base, No. 1, stands upon *lo*, No. 2, &c.

As to the divisions of the line GH, they may be found as in *fig.* 4.

*Figure* 1, *pl.* XXI, is a design for an ellipsoidal dome, the plan being elliptic, and one of the vertical sections circular. The ribs are constructed without trusses. In order to divide them as equally as possible, a purlin is introduced, to support the upper ends of the jack-ribs. As this dome is supposed to rise from an elliptic well-hole, the timbers are carried below the base, from *a*, *b*, *c*, *d*, *e*, *f*. No. 1 is the elevation, No. 2 the plan, showing the upper face of the wall-plate, purlin, and curb. Nos. 3, 5, 7, are the entire ribs, to be placed upon A, C, E, in the plan; and 4, 6, 8, are the jack-ribs, to be placed upon B, D, F, on the plan. The upper ends of all the ribs terminate upon the curb, or upon the purlin, with a *sally*, or *bird's mouth*, which is the usual method of fitting them.

*Figure* 2, *pl.* XXI, is a design for an hemispherical dome, constructed in the same manner as the elliptic dome, *fig.* 1.

In large roofs, constructed of a domic form, without trussing, the ribs may be made in two or more thicknesses, in such a manner that the common abutment of every two pieces, in the same ring, may fall as distant as possible from the abutment of any other two pieces, in a different ring. The number of purlins must depend upon the diameter of the dome.

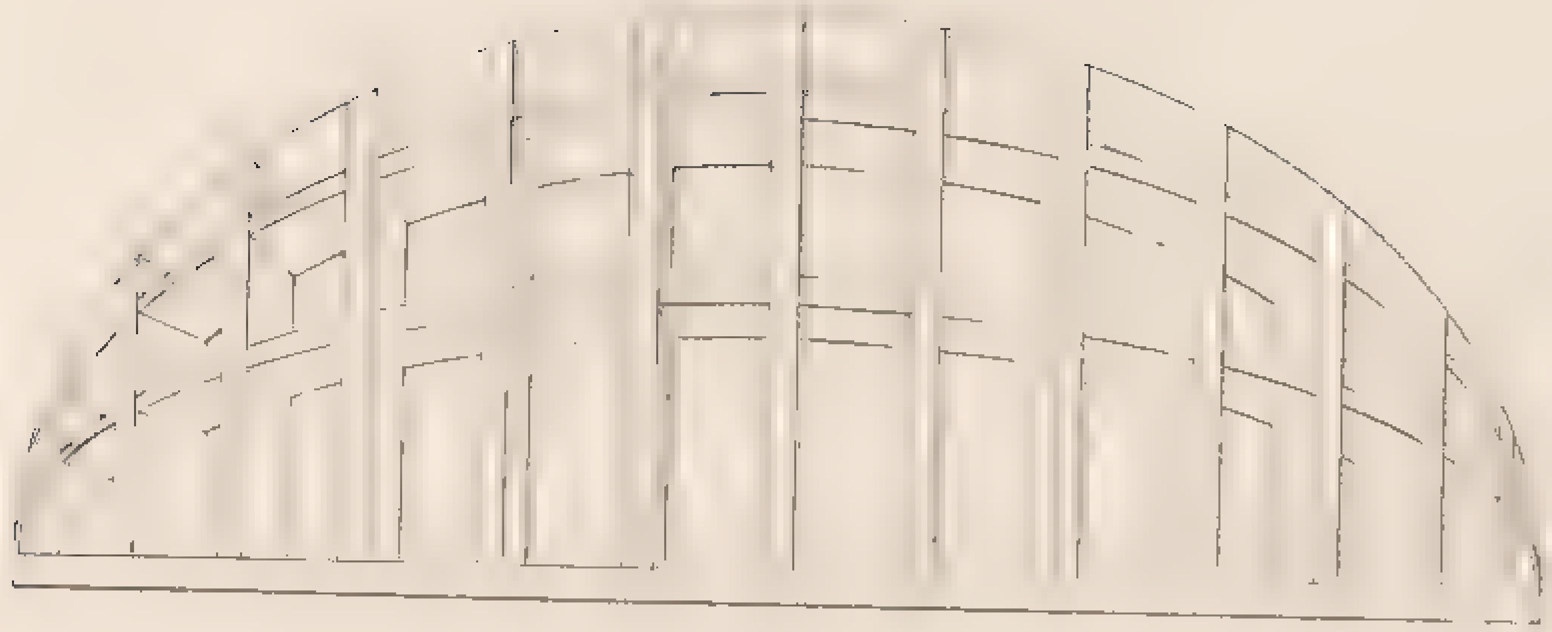
To find the form of the boards for an ellipsoidal dome, the plan being an ellipse, and the vertical section upon the axis-minor a semi-circle; so that the joints of the boards may be in planes passing through the axis-major of the plan.

Let ABCD, No. 1, *pl.* XXII, be the plan of the dome, AC the axis-major, and DB the axis-minor; E the centre. From E, with the distance ED, or EB, describe the semi-circle BFD. Divide the arc into such a number of equal parts, that one of them may be equal to the breadth of a board, and let the points of division be at 1, 2, 3, 4, &c. Draw the lines 1*a*, 2*b*, 3*c*, 4*d*, perpendicular to BD, cutting BD at the points *a*, *b*, *c*, *d*. Then, upon AC, as an axis-major, and upon E*a*, E*b*, E*c*, E*d*, as so many axes-minor, describe the semi-ellipses, A*a*C, A*b*C, A*c*C, A*d*C, which will represent the joints of the boards upon one side of the dome. Now, since all the sections of this dome, through the line AC, are identical figures, the vertical section, upon the line AC, will be identical to the half plan ABC, or ADC. Divide, therefore, BA into any number of equal parts, by the points of division *e*, *f*, *g*, *h*, *i*, *k*, *l*; the more, the truer the operation. Draw the straight lines *em*, *fn*, *go*, *hp*, *iq*, *kr*, *ls*, perpendicular to AC, cutting AC at the points *m*, *n*, *o*, *p*, *q*, *r*, *s*, and the semi-ellipse A*d*C, in the points *t*, *u*, *v*, *w*, *x*, *y*, *z*. On the straight line, GH, No. 2, set off the equal parts, E*m*, *mn*, *no*, &c., from each side of the centre E, each equal to one of the equal parts B*e*, *ef*, *fg*, &c., in the semi-elliptic curve, ABC, in the plan No. 1. Through the points *m*, *n*, *o*, *p*, &c., No. 2, draw *tt*, *uu*, *vv*, &c., perpendicular to GH. Make *mt*, *mt*, each equal to *mt* in the plan No. 1; and *nu*, *nu*, No. 2, each equal to *nu* in the plan No. 1; then, through all the points *t*, *u*, *v*, &c., draw a curve on each side of the line AC, to reach from A to C, and each curve will be the edge of a board.

No. 3 shows the longitudinal elevation; *viz.* on the line AC of the plan.

No. 4 exhibits the transverse elevation, the contour being identical to that of the section on the line AB.

Nº 3.



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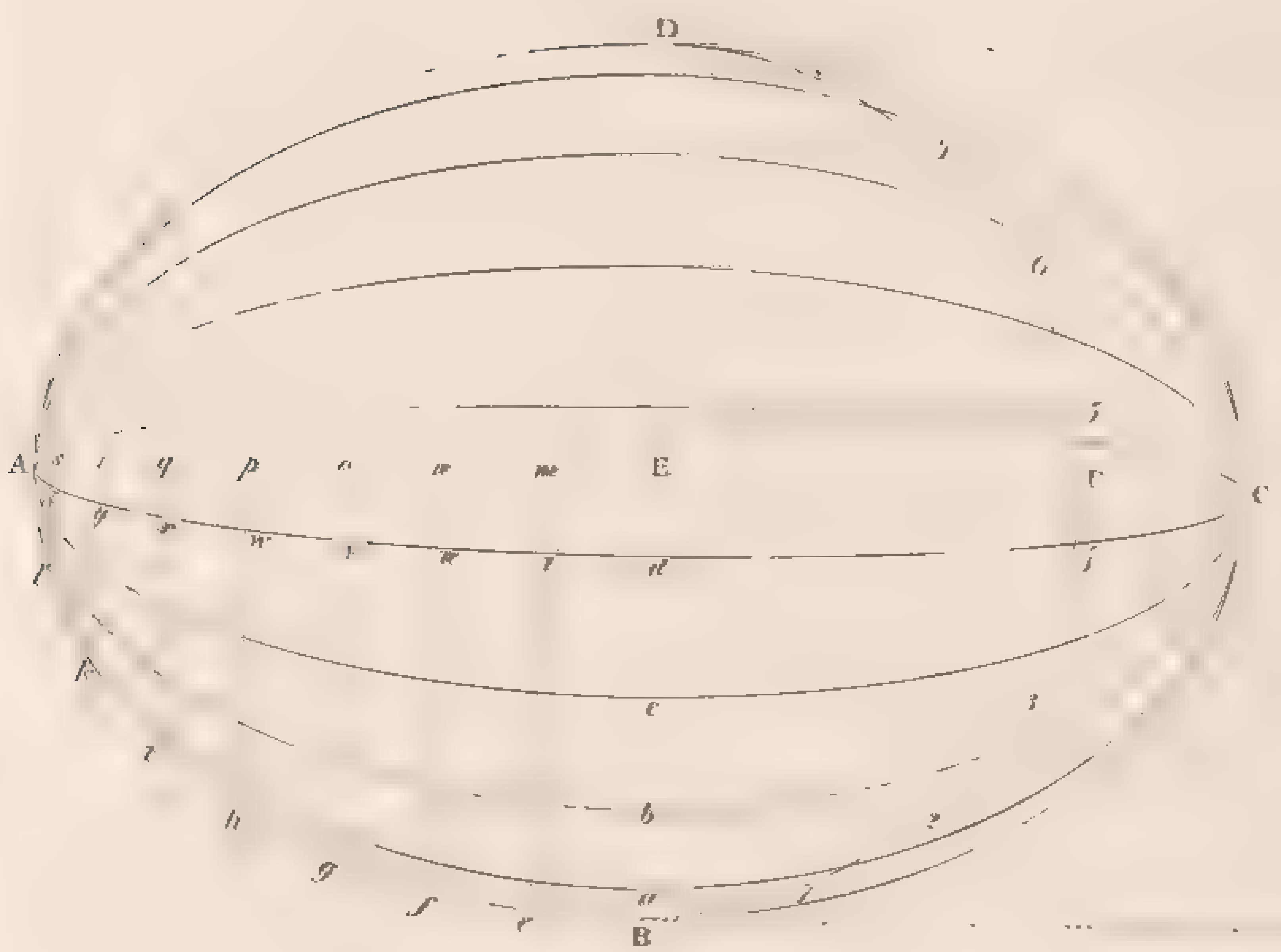
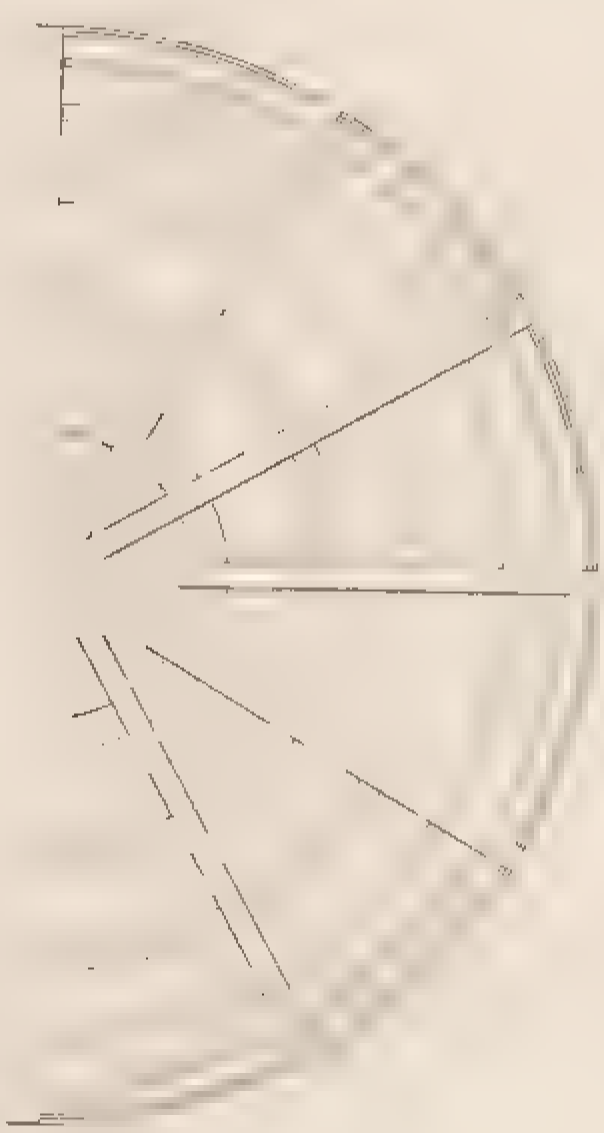
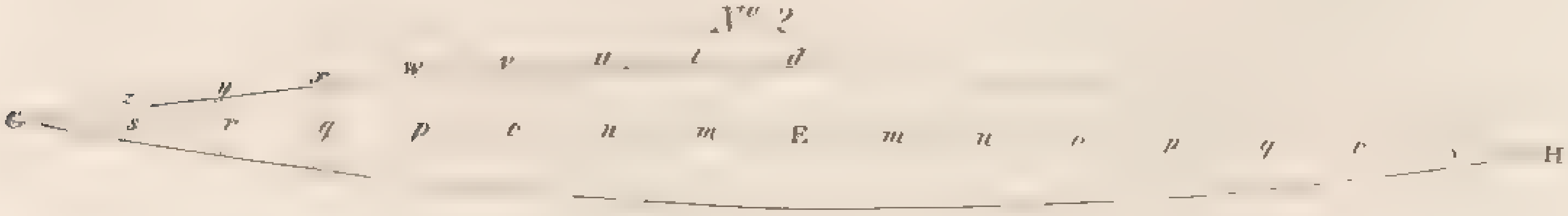



Nº 1.



Nº 2

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Engraved by W. Symns

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# DESIGNS FOR PARTITIONS.

*Fig. 1*

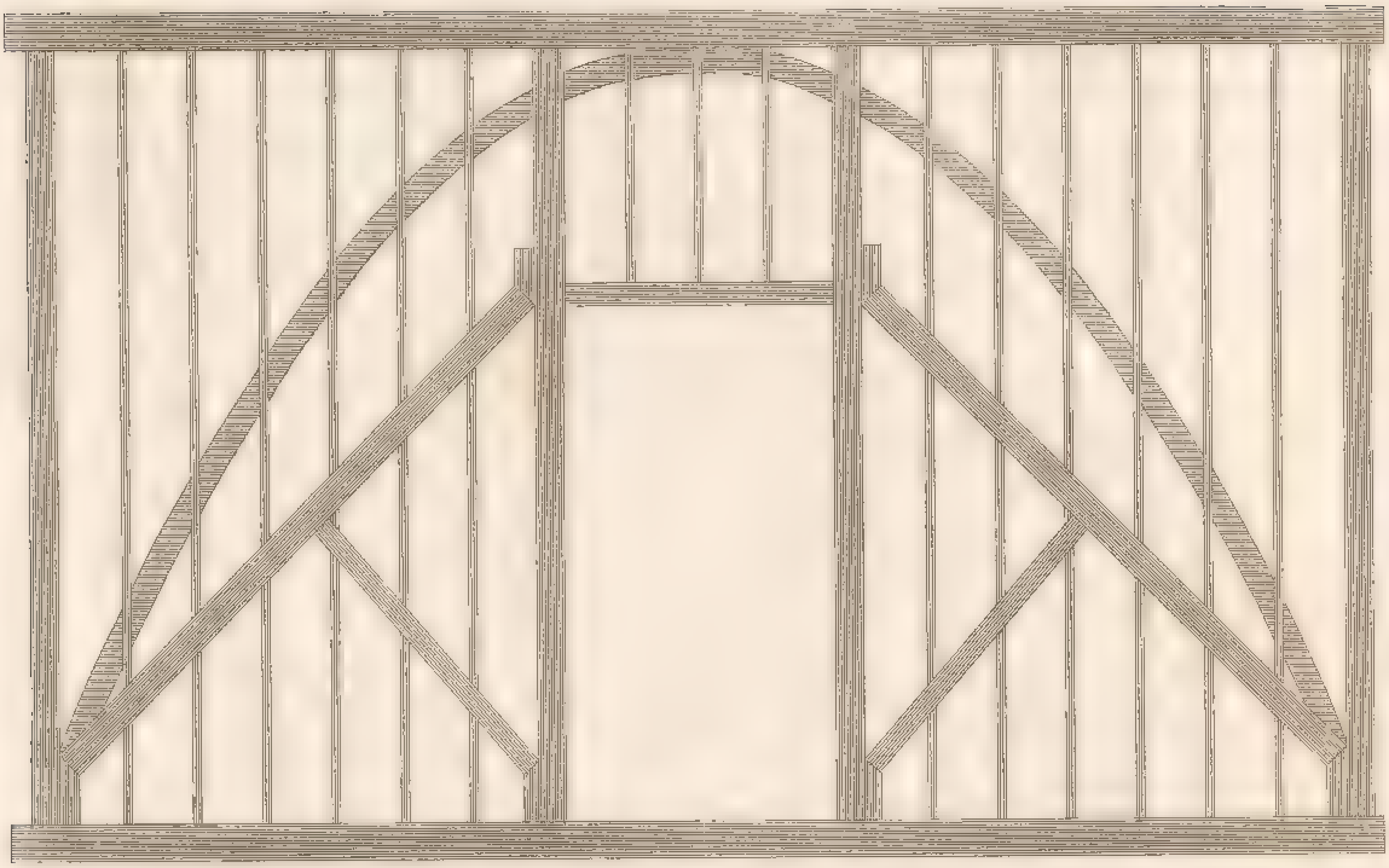
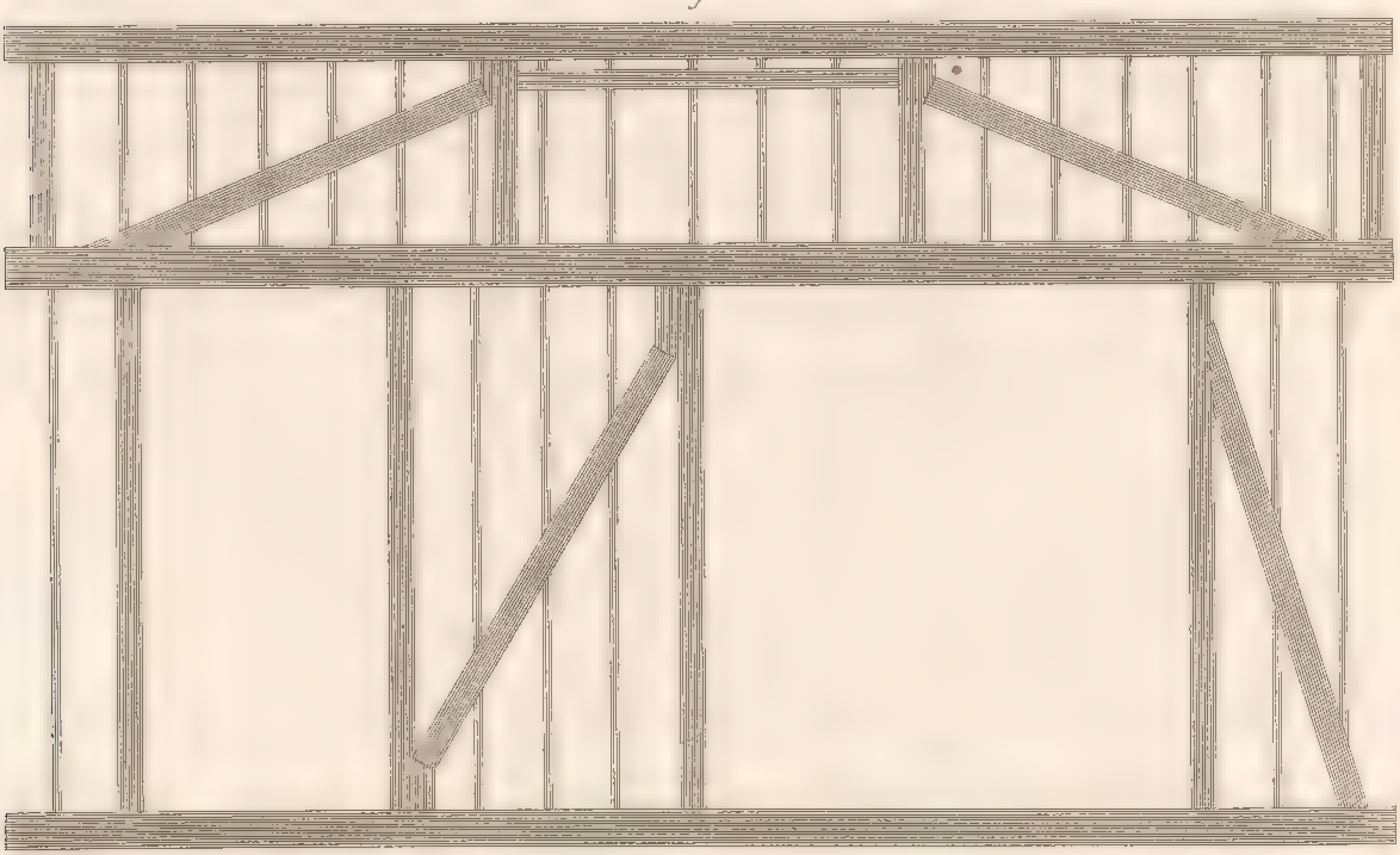


*Fig. 2*



*Drawn by P. Nicholson.*

*Engraved by W. Symns.*

*London, Published by Thos. Kelly, 17, Paternoster Row, Jan.y 1, 1822*

## DESIGNS FOR PARTITIONS.

PARTITIONS, in Carpentry, are the ribs of timber used for sustaining the lath and plaster.

It is evident that all single pieces of timber, when supported only at each extremity, will descend more and more towards the middle, and will obtain a curvature; but, if supported from any fixed points, will prevent that deflexion from the straight line.

*Figure* 1, *pl.* XXIII, is a design for a TRUSS PARTITION, with a door in the middle. In order to keep the timbers from descending, two braces are introduced, one on each side of the door-way, and the weight is discharged at each extremity of the sill. The two struts, which support the middle of these braces, are supported at the lower extremities on the bottom of the door-posts. Now the door-posts cannot descend, without pressing down the braces, and the braces cannot descend without forcing down the extreme post; but, as each end of the foot-beam, or sill, is supported, the extreme posts cannot descend; therefore the two braces cannot descend, and the posts on each side of the door-way cannot descend; consequently, the timbers will keep straight. But the weight of the quarters will still have a tendency to bind the braces: in order to prevent this effectually, the parabolic arch is here introduced.

*Figure* 2, *pl.* XXIII, is a design for a partition with two door-ways, one of them being a folding door. Here the braces on each side of the large opening not being each supported at each extremity of the sill, and as the space is not interrupted by openings, a complete truss is introduced above the two apertures, particularly as there is sufficient height for the action of the braces.

## DESIGNS FOR ROOFS.

*Figure* 1, *pl.* XXIV, is a design for a roof, of a very narrow span, having only one collar-beam, without a tie at the bottom. In this example the collar-beam acts as a tie, and is, therefore, in a state of tension: this ought not to be employed over a space exceeding fifteen or twenty feet wide.

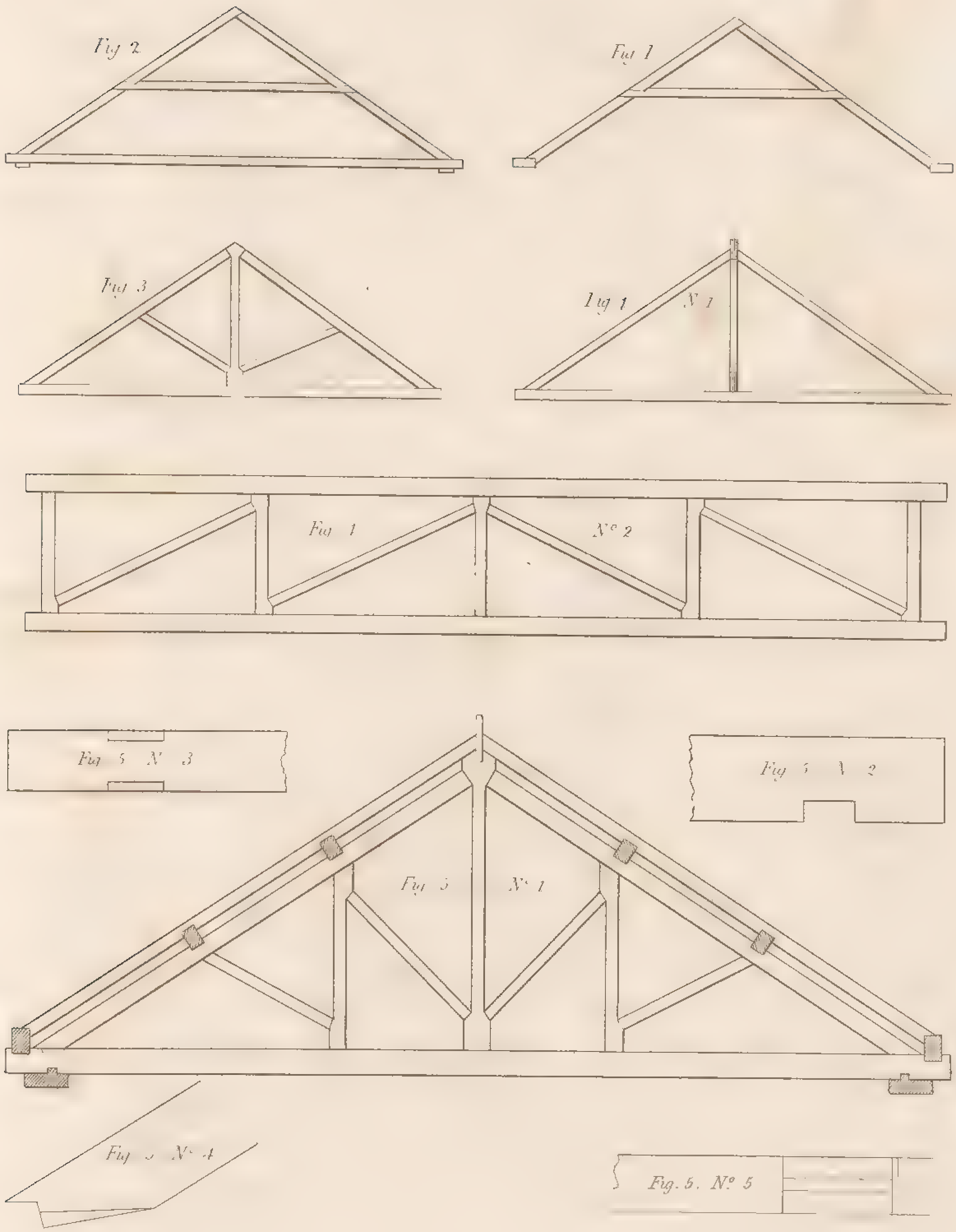
*Figure* 2 is a design for a roof with a tie-beam at the foot, and a collar-beam. Here the case is different; since the tie-beam is in a state of tension; the collar-beam is merely employed in keeping out the rafters, and is, therefore, in a state of compression. This truss may be employed where the span is from twenty to twenty-eight feet in width. If the two sides of this truss are equally loaded, it will remain stationary; but, if unequally, the equilibrium will be destroyed. This truss, without additional timbers, does not afford any support to the tie-beam.

*Figure* 3 is a truss free from these inconveniences; the tie-beam being supported by two struts or braces.

*Figure* 4, No. 1, in *pl.* XXIV, represents the side of a truss, with the ends of a longitudinal frame for supporting the tops of the rafters, which are here exhibited. No. 2 exhibits the frame as seen in the length of the roof, and is divided into several compartments, by means of a middle and two side posts. The ends of this longitudinal truss are fixed in the gables or cross-walls.

*Figure* 5, No. 1, is a design for a truss, with a king-post and two queen-posts. Here the manner in which the tie-beam is supported upon the wall-plates is shown. The sections of the pole-plates and purlins are also exhibited. No. 2, of this figure, shows the manner of notching down the small rafter upon the purlins, and the manner of notching the purlins upon the principals. No. 3 exhibits the manner in which the purlins are notched, to receive the small rafters, and in which the principals are notched, in order to receive the purlins. No. 4 shows the form of the tenon at the end of the

# DESIGNS FOR ROOFS.

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# DESIGNS FOR ROOFS.

Fig 1.

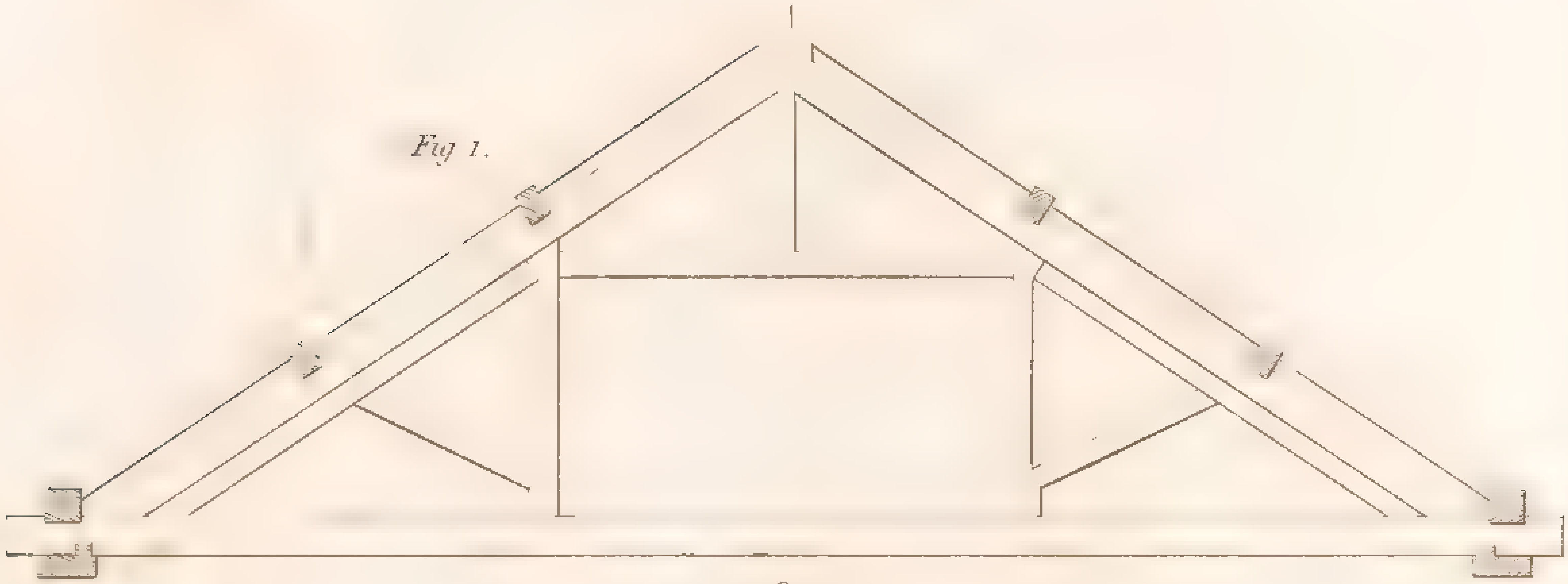
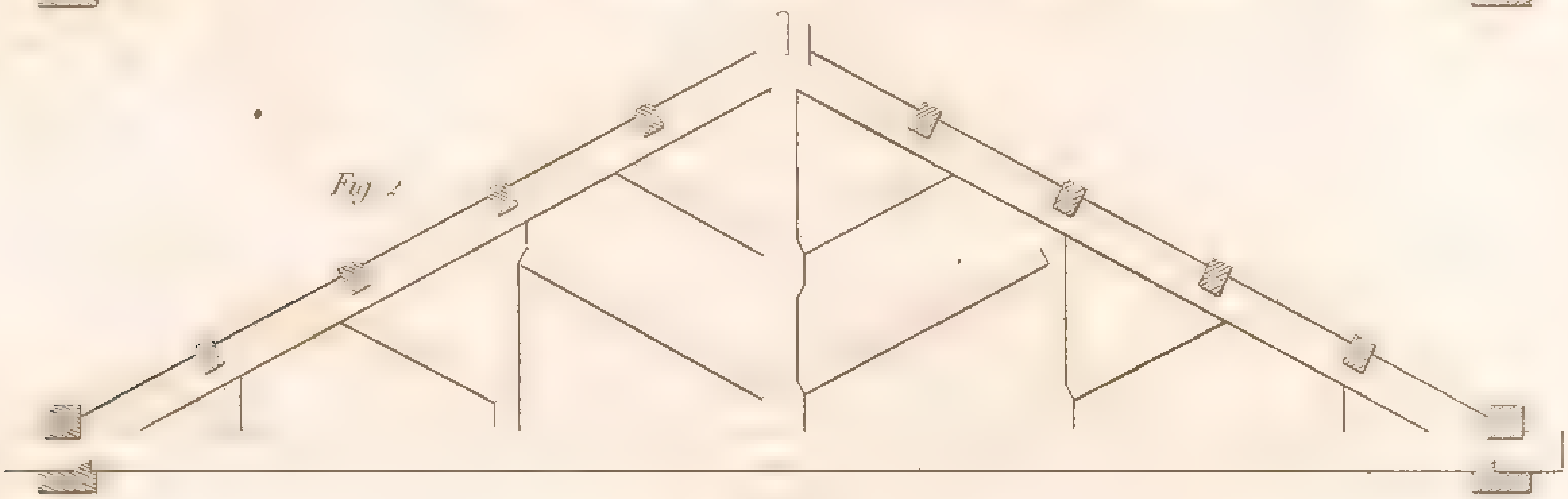


Fig 2.



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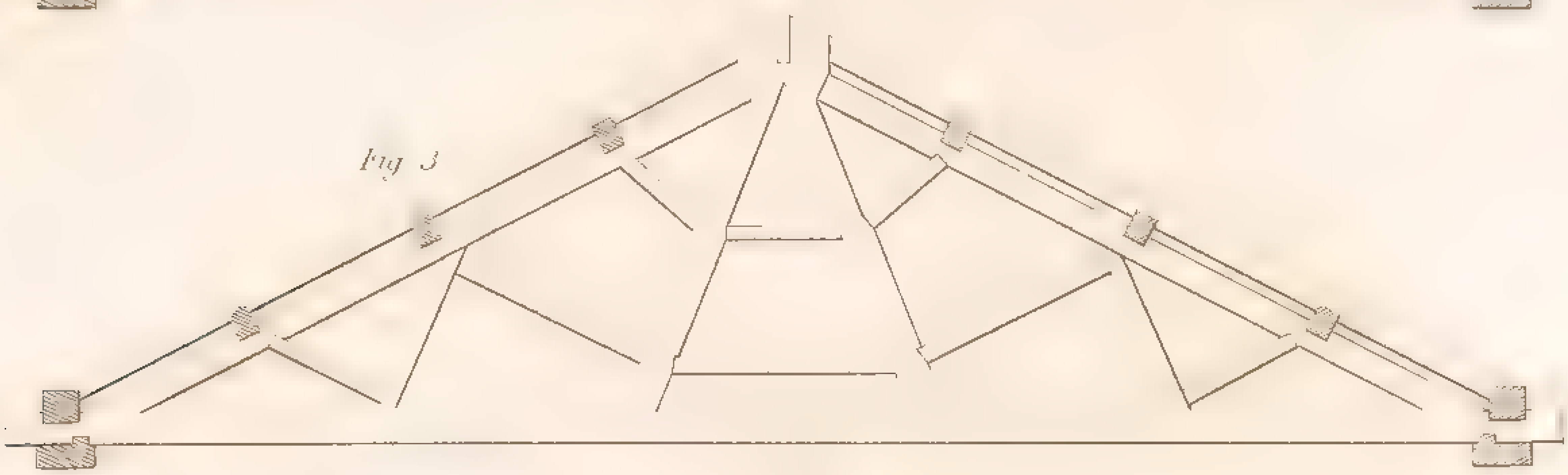

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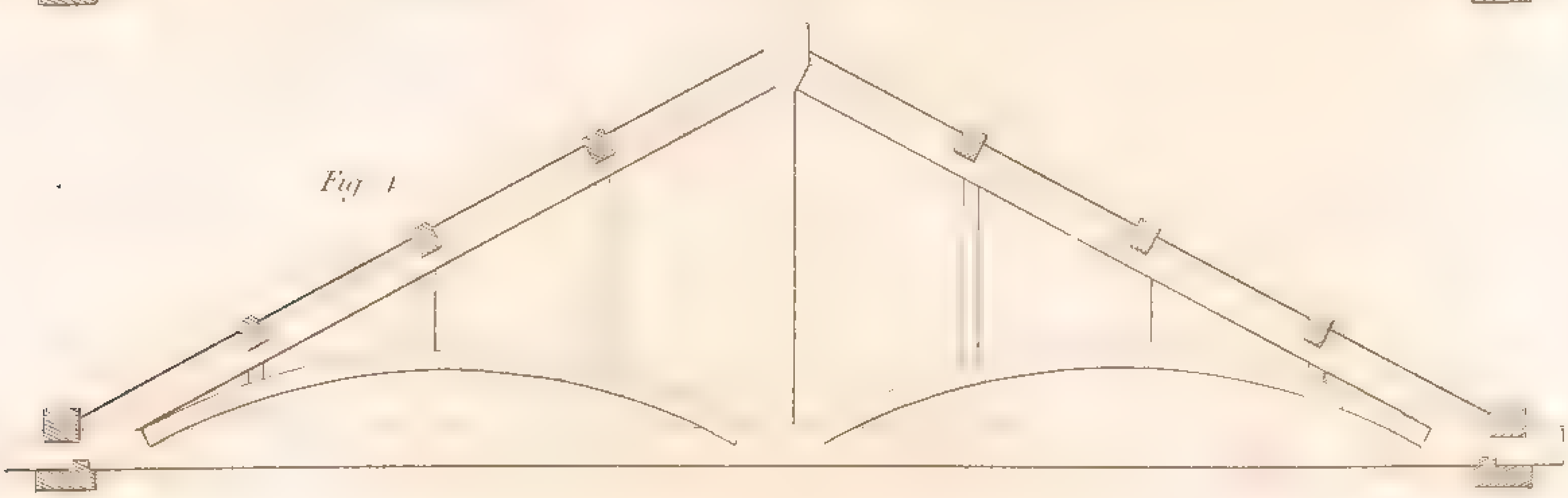

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PLATE XXVI.

# DESIGNS FOR ROOFS.

Fig. 1

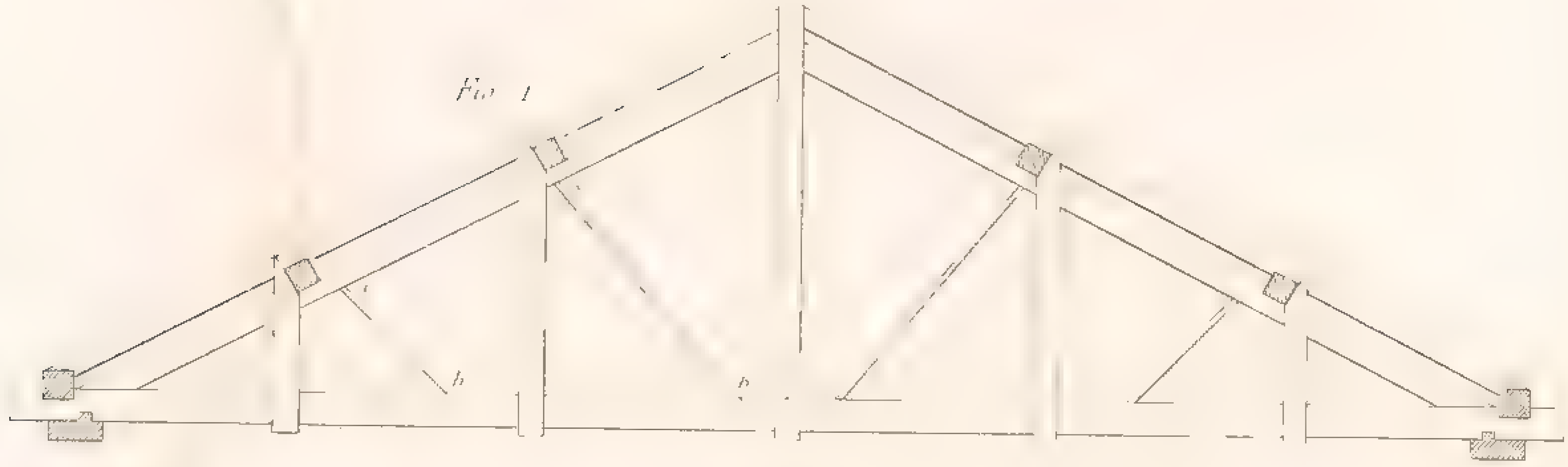


Fig. 2

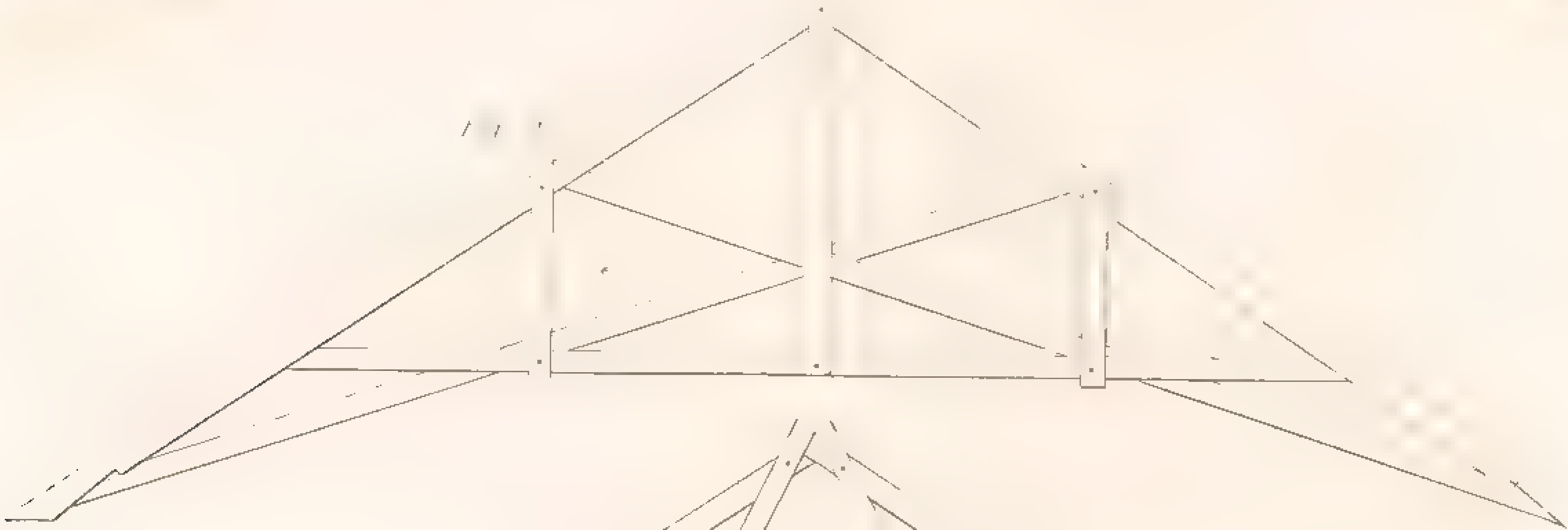


Fig. 3

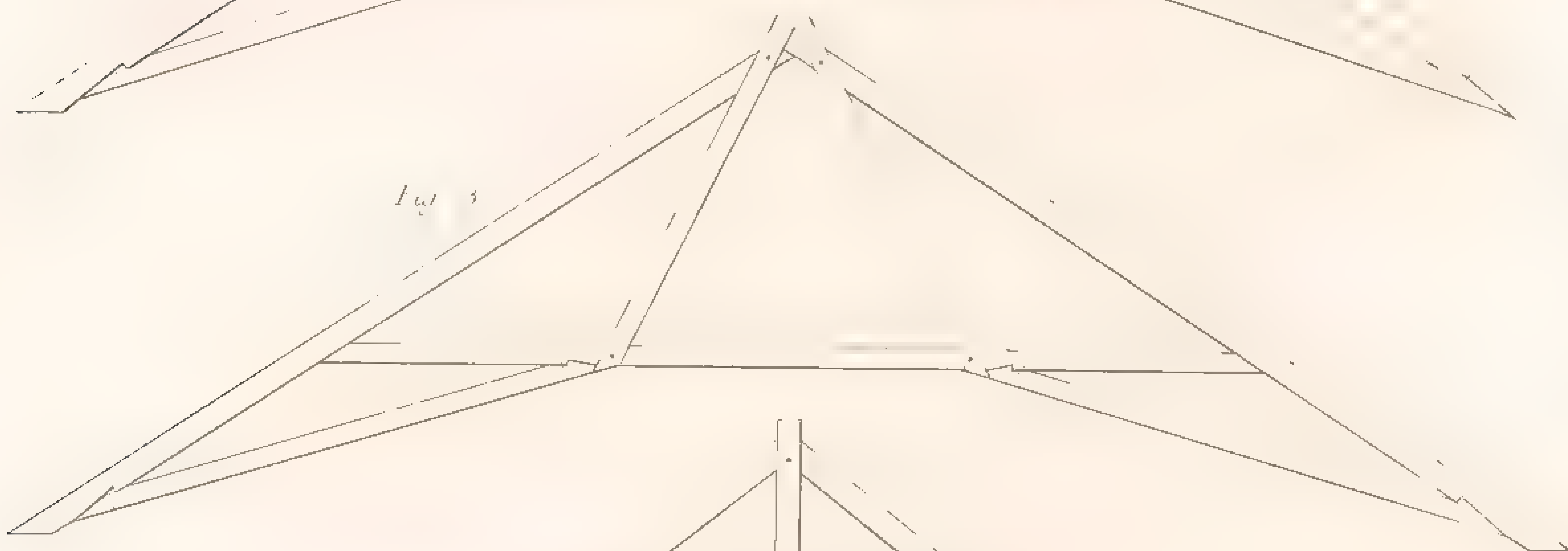
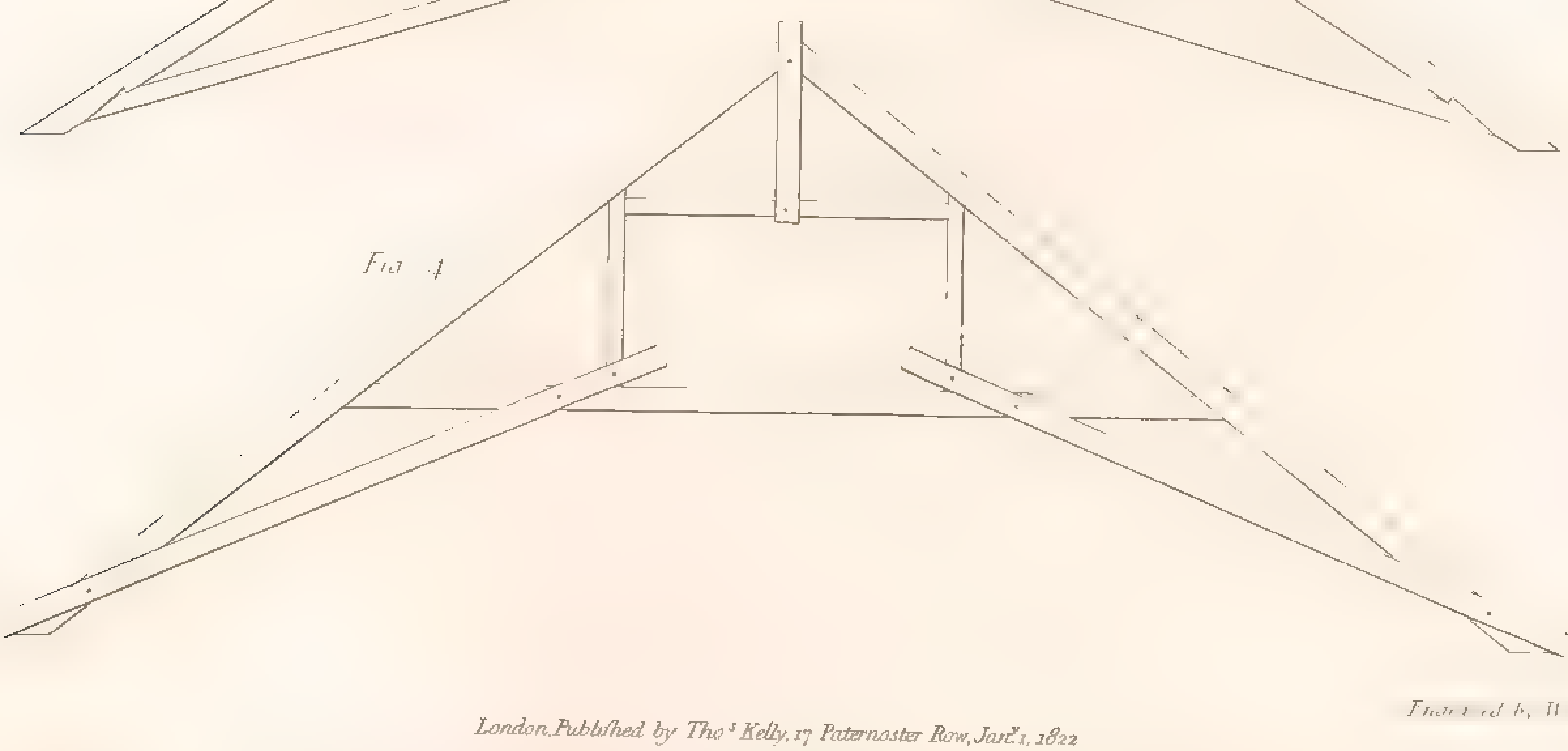


Fig. 4



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principal rafters, and the form of the rafter-feet; and No. 5, the manner in which the beam is mortised, in order to receive the feet of the principals. This roof is well adapted for the covering of an area of sixty feet span. Here the braces are all directed to the purlins which support the small rafters, and the small rafters the covering; so that the whole is firmly supported without danger.

*Figure* 1, *pl.* XXV, exhibits the design of a truss adapted to a sixty feet span. But, in this design, there is an opening in the middle, which is useful when rooms in the roof are required.

*Figure* 2, *pl.* XXV, is another design for a truss, with four purlins. This design may be employed in the covering of a span which extends between sixty and seventy feet.

*Figure* 3 is a design for a truss, which may be employed in a span extending from sixty to seventy feet, or even more, depending on the strength of the timbers. Instead of the posts, oblique ties are used.

*Figure* 4 is the design for a truss, where the purlins are supported by uprights, which rest upon arches: the tie-beam may be also suspended from the arches.

*Figure* 1, *pl.* XXVI, is another design for a truss. Here the posts are all made double and bolted; the braces, *a b*, *a b*, on each side, are supposed to be very stiff pieces of iron, shouldered on the inside, and nutted under the tie-beam, and under the principal rafters. This makes a very strong and good roof.

In order to make room for lofty apartments, when the building is of a limited height, and when a coved ceiling is required, the tie-beam must be placed above the feet of the principal rafter. *Figures* 2, 3, and 4, are designs for this purpose.

In *fig.* 2 the bracing timbers are halved together, and the posts are made double and bolted together. In *fig.* 3 the two braces, which perform the office of a king-post, or two queen-posts, are made double and bolted together. In *fig.* 4 the braces which join the rafter-feet and the king-post are made double, and bolted together: the queen-posts are mortised into the tie-beam and into the principal rafters, and the collar-beam into the queen-posts.

*Figure* 1, *pl.* XXVII, is the design for the truss of a kirb-roof, with a door in the middle.

*Figure* 2 is the design for the truss of a kirb-roof, with two doors, one at each extremity. In this example the king-post is made double, and the two braces nearest the bottom. This mode of fixing posts and braces is much firmer than bare mortising and tenoning.

*Figure* 3 is a design for a flat roof, to be covered with lead.

*Figure* 1, *pl.* XXVIII, is the design for a roof in several stages, adapted to warehouses. The explanation of the several parts are as follow: *Figure* 2 is the longitudinal truss for the upright frames, which rest upon the main tie-beams, and which support the oblique parts that connect the upper stage. *Figure* 3 exhibits the longitudinal truss in the side of the roof, and which may be made into windows. *Figures* 4 and 5 show the abutting joints, made of cast-iron, for receiving the lower and upper ends of the braces. *Figure* 6 shows the cast-iron abutments used in the truss, *fig.* 2.

*Plate* XXIX exhibits the various methods for TRUSSING GIRDERS.

*Figure* 1, No. 1, exhibits the side of a trussed girder with two braces, or *trusses*, as they are called. Here it is proper to observe that, though the sides should be firmly bolted together, the two braces should be entirely clear of the bolts, except at their lower extremities. No. 2 is the plan of the truss.

*Figure* 2 is the design for a truss-girder in three parts, with two queen-bolts. No. 1 is the side, or elevation, of the truss; and No. 2, the plan of the same.

*Figure* 3 is a section of either of the above-mentioned truss-girders, at the abutments.

*Figure* 4, a section of the king-bolt, nut, and washer, across the girder.

*Figure* 5 is a section of the king-bolt, *fig.* 1, *No.* 1, taken longitudinally, and exhibiting the nut and part of the braces.

*Figure* 6 is another design for a truss-girder, divided into four parts. But here it must be observed that, as the depth of the timber is not great, the effort of the braces to prevent the falling of the girder must be greatly insufficient; and, therefore, if height will allow, the proportion shown in *fig.* 7 will fully answer the purpose.

# DESIGNS FOR ROOFS.

Fig. 1.

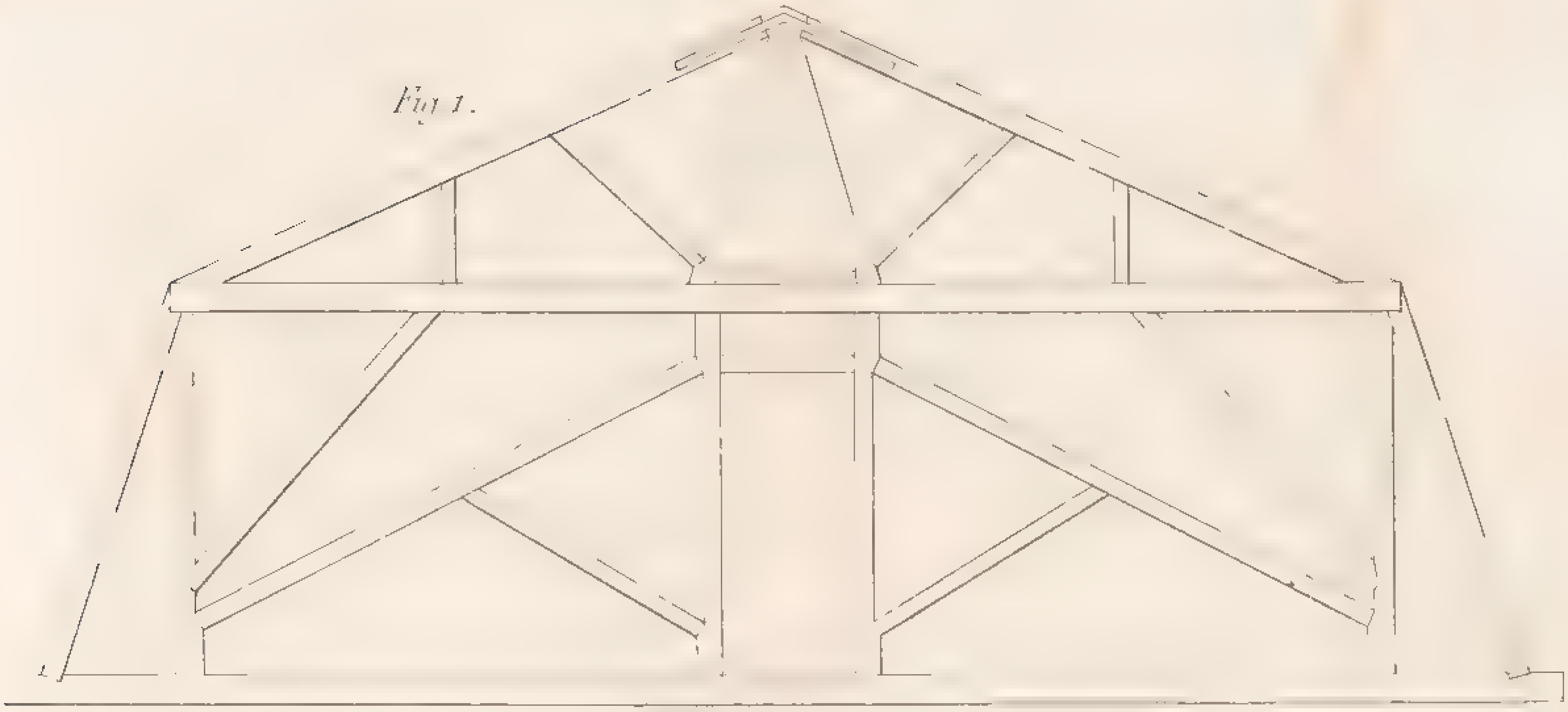


Fig. 2.

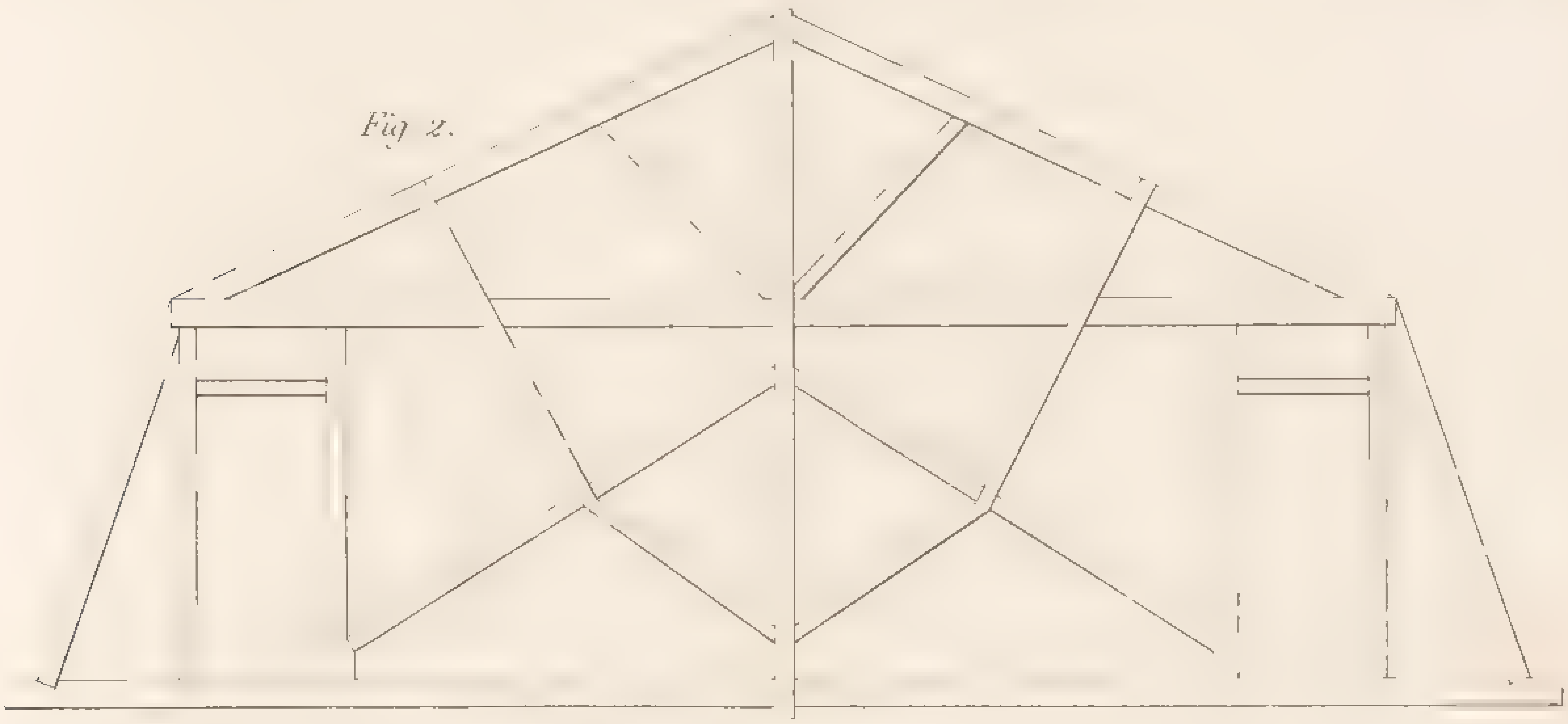
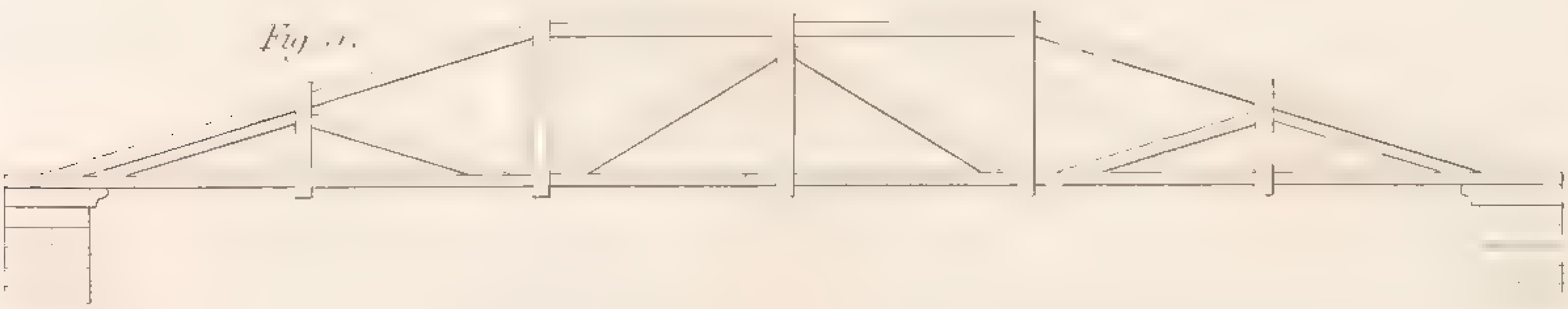


Fig. 3.



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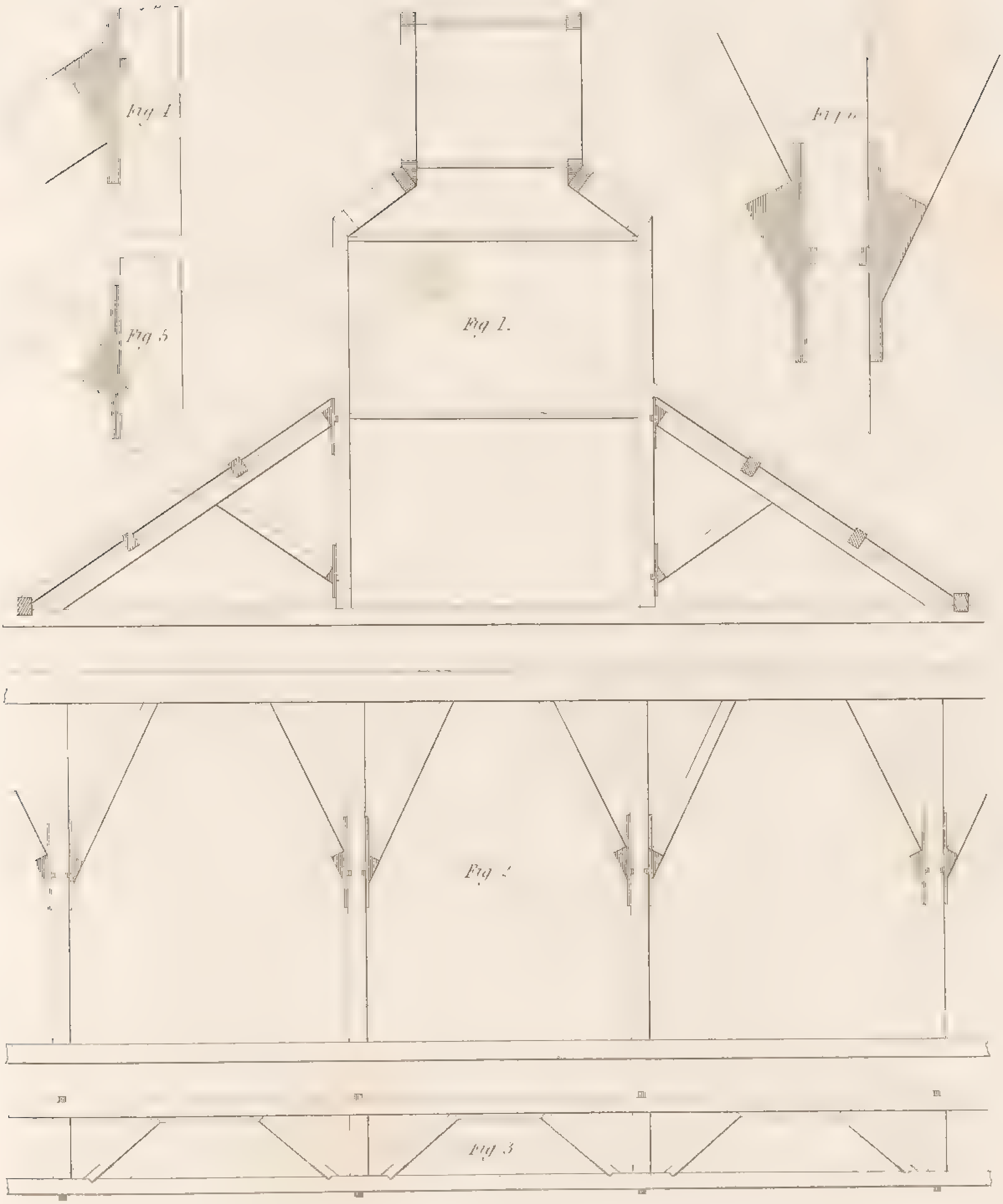
# DESIGNS FOR ROOFS.



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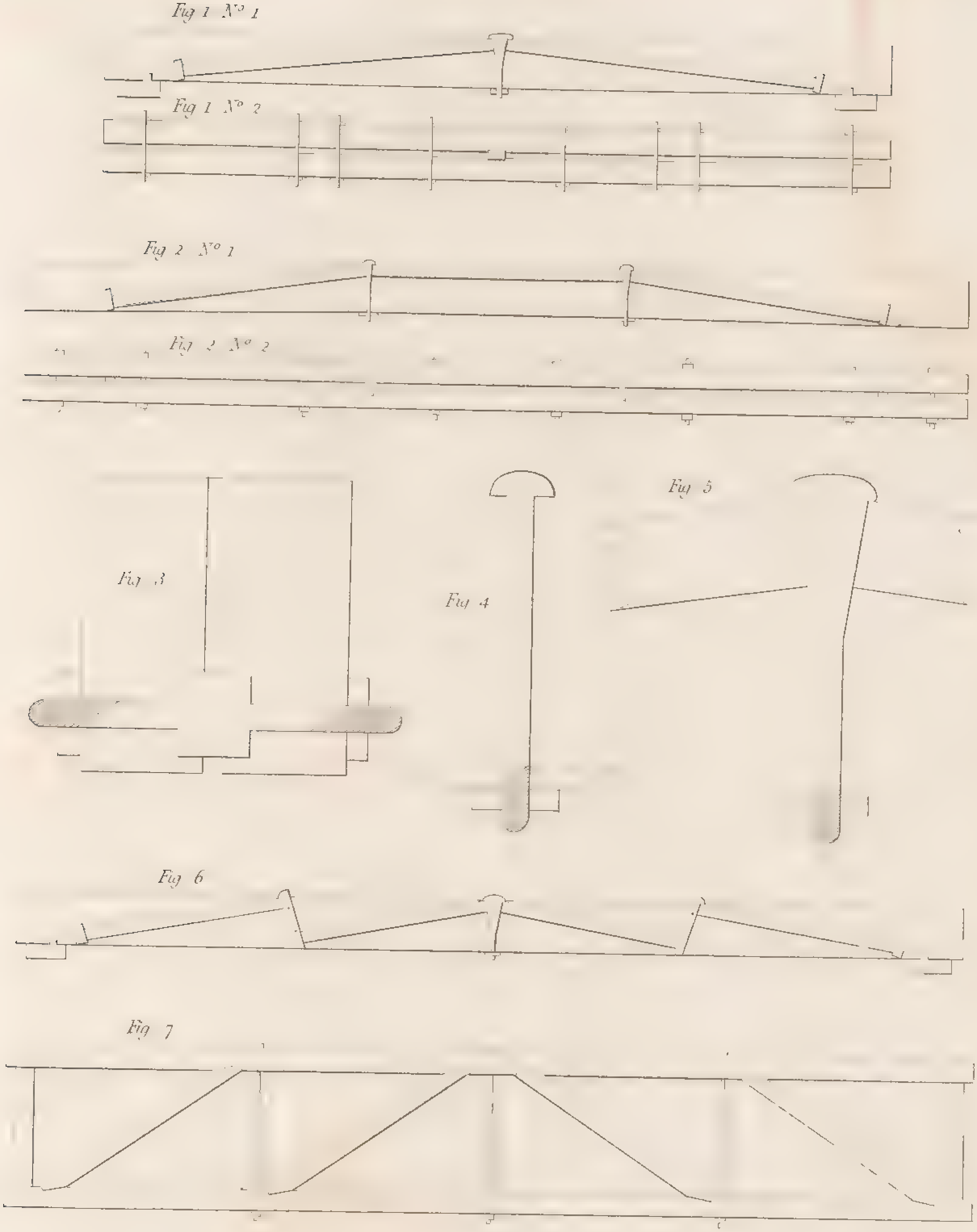
# TRUSS GIRDERS.



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# CHAPTER III.

## JOINERY.*

JOINERY is the art of uniting and framing wood, for the internal and external finishing of buildings. In Joinery, therefore, it is requisite that all the parts shall be much more nicely adjusted to each other than in carpentry, and all the surfaces which are to be exhibited to the eye shall be made perfectly smooth.

The wood employed in Joinery is denominated STUFF; and of this there are BOARDS, PLANKS, and BATTENS; thus distinguished according to their breadths: BATTENS are from two to seven inches wide; BOARDS, from seven to nine inches; and PLANKS, from nine inches to any indefinite breadth.

The OPERATIONS of JOINERY consist in making surfaces of various forms; also of GROOVING, REBATING, MOULDING, MORTISING, and TENONING.

SURFACES, in Joinery, may be either plane or curved; but they are most frequently plane. Every kind of surface is first formed in the rough, and then finished by means of tools, which will be described hereafter.

GROOVING and REBATING consist in taking or abstracting a part which is every where of a rectangular section. A REBAT is formed close to the edge of the stuff; and a GROOVE, at some distance from the edge.

A MORTISE is a cavity formed within the surface, for the purpose of receiving the end of a piece of timber, to be joined at a given angle. The end, which must be very nicely fitted into the mortise, in order to make the two

* CENTERINGS, STRENGTH OF TIMBER, &c.—It may here be proper to notice that a Chapter on CENTERINGS, particularly the CENTERINGS of BRIDGES, with the application of timber to other purposes than those already explained, will follow the Chapters on Joinery, &c.: in the same Chapter we shall, also, treat on the COMPARATIVE STRENGTH of TIMBER, &c.

pieces as strong as possible, is called a TENON. As the sides of the mortise are generally perpendicular to the sides of the stuff, and at some distance from the sides of the piece in which the mortise is, a tenon is generally stopped by projecting sides, which are closely fitted upon the side of the piece of wood in which the mortise is made; and the parallel faces of both are made flush, and so closely united, as to appear almost like one single piece. The surface of the piece which has the tenon, and which comes in contact with the surface of the piece in which the mortise is made, is called the *shoulder* of the tenon.

FRAMES are joined together, so as generally to form externally a rectangle, and internally one, two, or more, rectangular openings: these openings are closed with thin boards, fitted into grooves round the edges, called PANELS. In ornamental work, the edges of the frame next to the panels, the two extreme vertical pieces of the frame, are denominated the STILES; all the cross-pieces are denominated RAILS; and vertical pieces, that separate the panels, MOUNTINGS.

PLANKS are joined together by planing the edges straight and square, and rubbing them together with hot glue until the glue has been almost forced out of the joint; then the ends and the proper faces being brought to their places, the rubbing is stopped, and, when the glue is quite dry, the two boards thus fixed will be almost as strong as one entire board.

MOULDINGS have several names, according to their forms, connexion, situation, or size. When the edge of a thin slip of wood is semi-circular, it is said to be *rounded.*

*Figure* 1, *plate* XXX, represents the section of a piece rounded on the edge.

When a semi-cylinder is formed on the edge of a piece of wood, within both surfaces, so that the diameter may be parallel to one side, this semi-cylinder is called a BEAD; and the recess, between the surface of the cylinder and the solid wood upon the side, which is parallel to its diameter, is denominated a QUIRK; and the whole part thus formed is called a BEAD and QUIRK.

# MOULDINGS.

PLATE XXX.

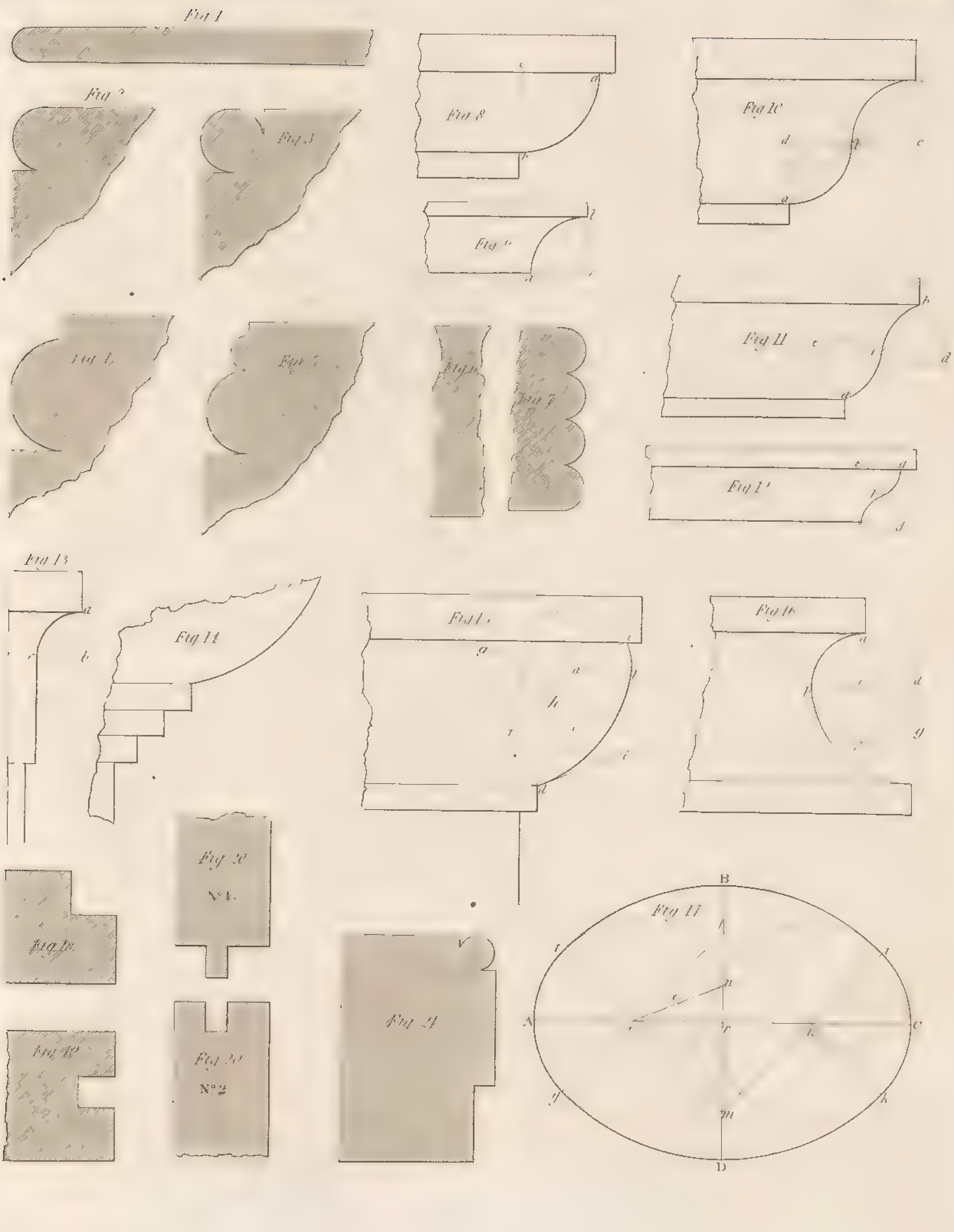

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*Figure* 2, *plate* XXX, is the section of a piece of wood, where a bead and quirk is run on the edge.

BEAD and DOUBLE QUIRK is when a three-quarter cylinder is run on the edge, so that the surface of the cylinder may touch each adjoining face.

*Figure* 3 exhibits the section of a *bead* and *double quirk.*

A TORUS-MOULDING consists of a semi-cylinder, and two rectangular surfaces, one perpendicular to the diameter, and the other in the diameter produced.

*Figure* 4 is a *torus-moulding:* the small rectangular surface in the plane of the diameter is denominated a FILLET.

*Figure* 5 exhibits the section of a DOUBLE TORUS.

A FLUTE is the concave surface of the section of a cylinder or cylindroid, depressed within the surface of a piece of wood.

*Figure* 6 exhibits the section of a piece of wood with three *flutes.*

When a piece of wood is formed into two or more semi-cylinders, touching each other, the semi-cylinders are called REEDS, and the piece of wood is said to be *reeded.*

*Figure* 7 exhibits the section of a piece of wood with four *reeds* wrought upon it.

*Figure* 8 is the section of a moulding denominated a QUARTER ROUND. It consists of the fourth part of the convex surface of a cylinder.

*Figure* 9 is the section of a moulding denominated a CAVETTO, consisting of the fourth part of the concave surface of a cylinder.

*Figure* 10 is the section of a CYMA-RECTA, consisting of a quarter round and cavetto joined together by one common tangent plane; each part being the quarter of the surface of a cylinder, the one concave, and the other convex.

To draw this curve, join the extremities $a$ and $c$ of the moulding: bisect $ac$ in the point $b$, and draw $de$ parallel to the longitudinal direction of the moulding; make $ad$ and $ce$ perpendicular to $de$; from $d$, with the radius $da$, describe the arc $ab$; from $e$, with the radius $ce$, describe the arc $bc$; and $abc$ is the moulding required.

*Figure* 11 is also the section of a *cyma-recta,* of which the concave and convex parts are equal portions of a cylinder, but each portion less than the quarter.

To draw this curve, join the extremities *a* and *b,* and bisect *ab* in *c*: from *a,* with the radius *ac,* describe an arc *ce*; and from *b,* with the radius *bc*; describe an arc, *cd*; from *c,* with the radius *ca,* describe an arc, *ae,* as also the arc *bd.* With the same radius, from the centre *e,* describe the arc *ac*; and with the same radius, from the centre *d,* describe the arc *cb*; then *acb* is the curve, which is the section of the surface of the moulding.

*Figure* 12 is the section of a moulding of the OGEE kind, called a CYMA-REVERSA: this moulding is of the same form as the cyma-recta, except that, in the cyma-recta, the concave portion of the moulding is the most remote from the eye; whereas, in the cyma-reversa, the convex part is the most remote from the eye.

*Figure* 13 is the section of a moulding called a SCAPE, which is composed of the quarter of the circumference of a cylinder, and a plane surface, which is a tangent to the cylindric surface, in the line of their meeting.

*Figure* 14, part of the section of an *ovolo* with three *fillets,* which, when circular, or encompassing a column, are called ANNULETS.

*Figure* 15 is the section of a moulding denominated a QUIRKED OVOLO. The method of drawing it is thus: Suppose it were required to touch the line *de* at the point *d*: draw *dg* perpendicular to *de*; describe the circle *bci*; make *df* equal to the radius of the circle *bci,* and join *af.* Bisect *af* by a perpendicular, *gh,* meeting *af* in *h*; then, with the radius *dg,* describe the arc *db*: *dbc* will then be the ovolo required.

*Figure* 16 is the section of a concave moulding called a SCOTIA. To form this moulding, describe the circle *dabf,* and draw *cd* perpendicular to the fillet. Make *cg* equal to the radius of the circle to be described, and let *e* be the centre of that circle: join *ge,* and bisect *ge* by the perpendicular *df*: from *d,* with the radius *dc,* describe the arc *cb,* and *cba* will be the scotia required.

*Figure* 17 exhibits the METHOD OF DRAWING AN OVAL, to any length and breadth required. Draw the greater axis AC, and let *r* be the centre;

# FRAMING OF ANGLES.

Fig. 1.

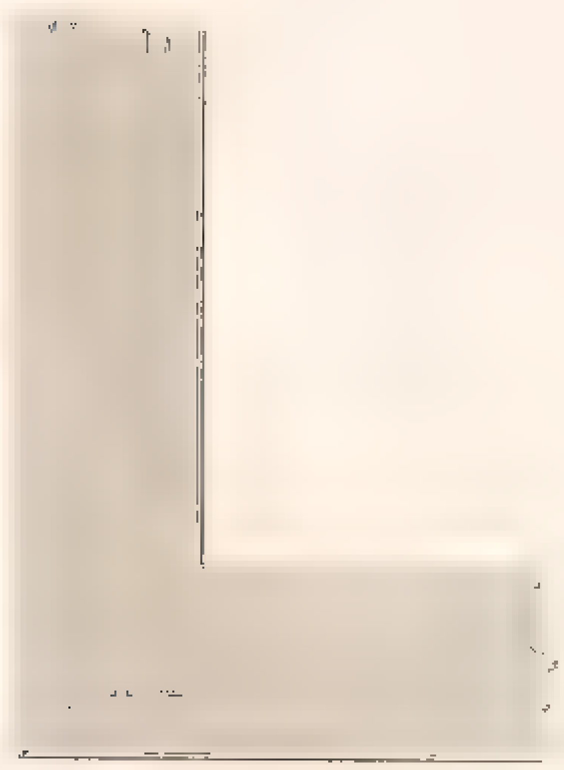


Fig. 2.

Fig. 3.

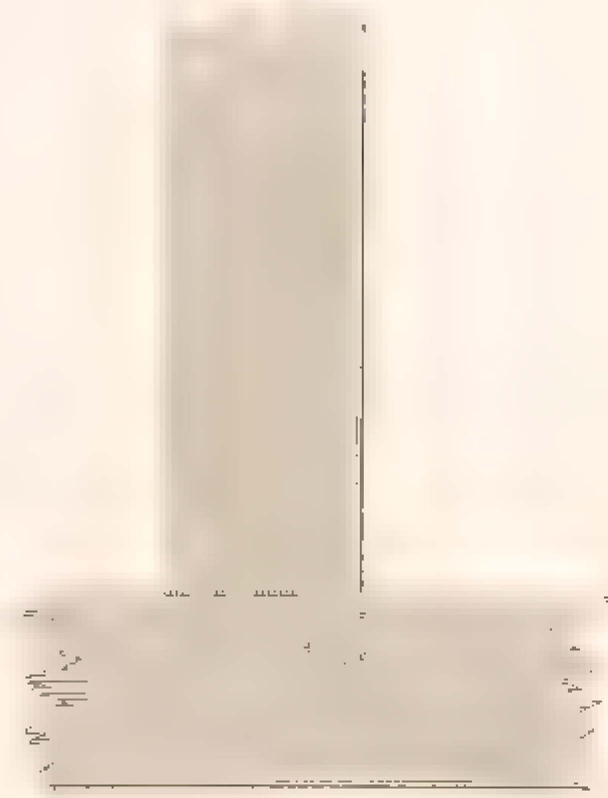


Fig. 4.

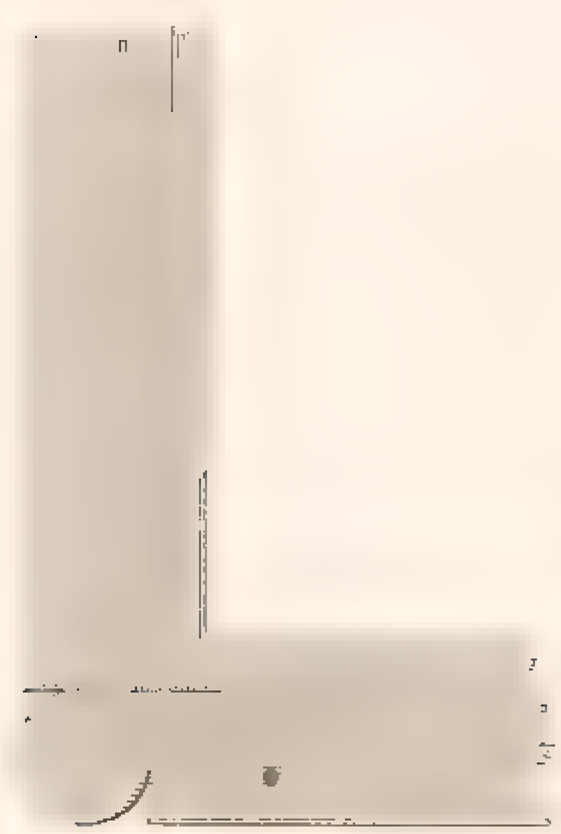


Fig. 5.

Fig. 6.

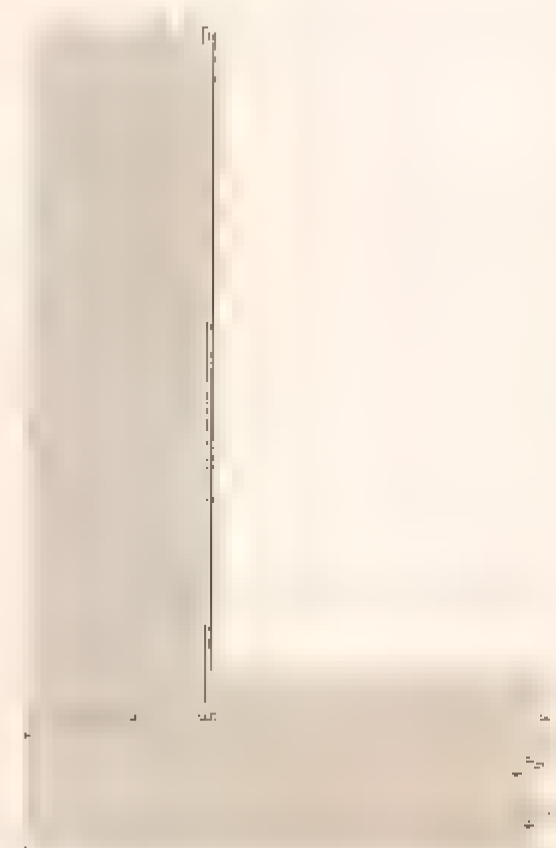


Fig. 7. Nº 1.

Fig. 7.

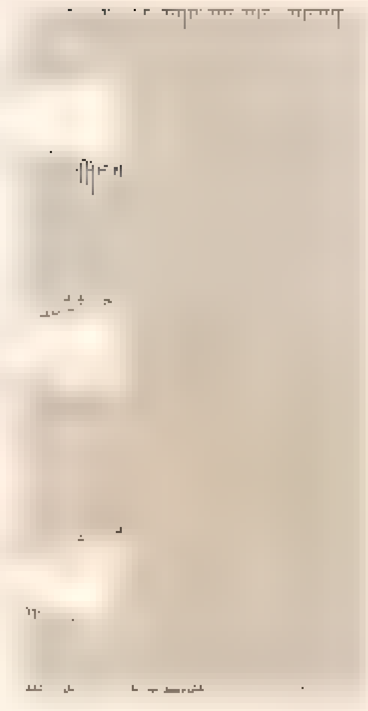


Fig. 8. Nº 2.

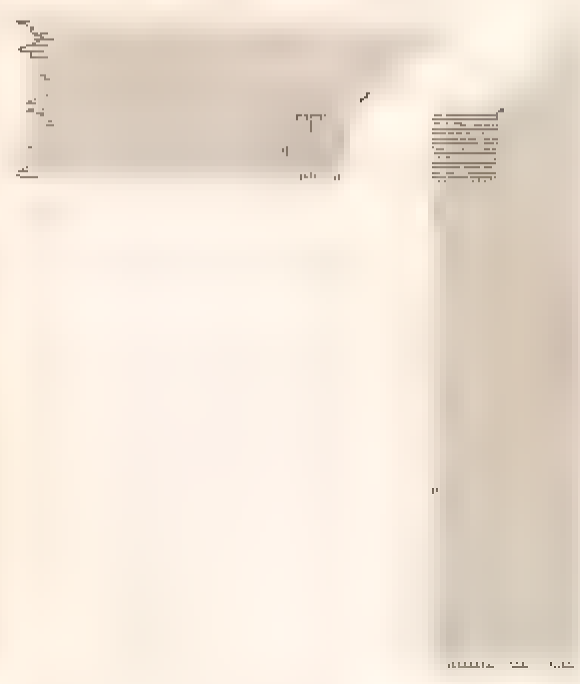


Fig. 8.

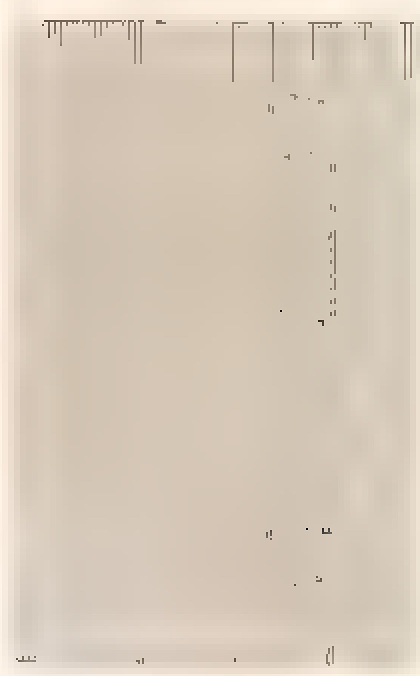
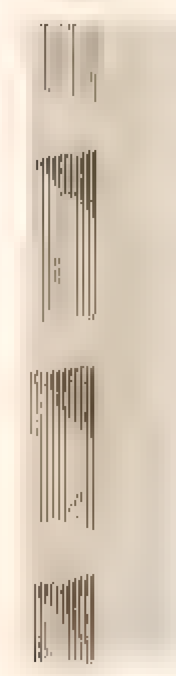


Fig. 8. Nº 1.



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through $r$ draw BD perpendicular to AC. Make $r$A and $r$C each equal to the semi-greater axis, and $r$B and $r$D each equal to the semi-lesser axis. Take half the difference of the two semi-axes from the lesser semi-axis, and, with the remaining part, as a radius, from the centre $e$, describe the arc $g$A$f$. Make B$n$ equal to A$e$, and join $en$. Bisect $en$ by the perpendicular $om$, meeting BD at $m$: join $me$, and produce $me$ to $f$. Make $rl$ equal to $rm$, and join $le$, and produce $le$ to $g$. Make $rh$ equal to $re$; join $lh$, and produce $lh$ to $k$; also, join $mh$, and produce $mh$ to $i$. With the centre $m$, and the radius $mf$, describe the arc $f$B$i$; and, from the centre $l$, with the radius $lg$, describe the arc $g$D$k$; lastly, from the centre $h$, and with the radius $hk$, describe the arc $k$C$i$, which will complete the oval required.

*Figure* 18 represents the section of a piece of wood which is said to be rebated. *Figure* 19, the section of a piece of wood said to be *grooved*. *Figure* 20, the sections of two pieces of stuff, *grooved* and *tongued* together: No. 1 shows the *tongue*, and No. 2 the *groove*, so adapted to each other that they may be joined closely together. This method is used where it is required to join many boards together, so as to make one board, in order to prevent wind or air from coming through the joints between every two boards.

*Figure* 21 represents the section of a piece of stuff said to be *rebated* and *beaded*.

---

## ON THE VARIOUS FORMS OF FRAMING BOARDS WITH THEIR EDGES JOINED, SO AS TO FORM A RIGHT ANGLE, ONE BOARD WITH ANOTHER. *Pl.* XXXI.

*Figure* 1 shows the method of *mitreing* the ends of boards for *dado*,* or the like, at an external angle.

*Figures* 2 and 3, the method of joining troughs together. *Figure* 3 may also be applied to joining dado together, at an internal angle.

*Figure* 4, the method of joining any kind of linings together, at an external angle; a bead being stuck on the edge, in order to conceal the joint.

* By *dado* is meant the plane surface between the base and surbase of a room, or between the base and cornice of the pedestal of a column.

*Figure* 5, a plane *mitre,* used for various purposes; but, on account of its weakness, the method in *fig.* 1 is to be preferred.

*Figure* 6 is another method of joining angles by a plain *rebate.*

*Figure* 7 exhibits the method of *dove-tailing*: No. 1 represents the pins or male part, and the other the female dove-tails.

*Figure* 8 shows the method of making secret dove-tails. At No. 1 the ends of the male dovetails are shown; *fig.* 8 itself is the outside. No. 2 shows the section of both parts.

---

## OF DOORS. (*Pl.* XXXII.)

*Figure* 1 represents a SIX-PANEL DOOR, having *ovolo* and *fillet* on the stiles, with plane panels.

*Figure* 2 represents FOLDING DOORS, which meet together upon a lap-joint, exhibiting a bead on both sides of the door.

*Figure* 3 exhibits BEAD and BUTT.

*Figure* 4, BEAD and FLUSH. The difference between bead and butt and bead and flush is this: In bead and butt, the bead is run on the edges of the panel; but in bead and flush, the bead is run round all the four edges of the frame.

*Figure* 5, section of part of the stile and panel of a square frame.

*Figure* 6, section of part of a stile and panel moulded with quirk-ovolo and fillet; the panel being flat on both sides.

*Figure* 7, section of part of a stile and panel, having quirked ovolo and bead on the framing, with square panel.

*Figure* 8, section of a part of the stile and panel of a door, with quirked semi-reversa on the framing.

# DOORS.

*Fig. 2.*

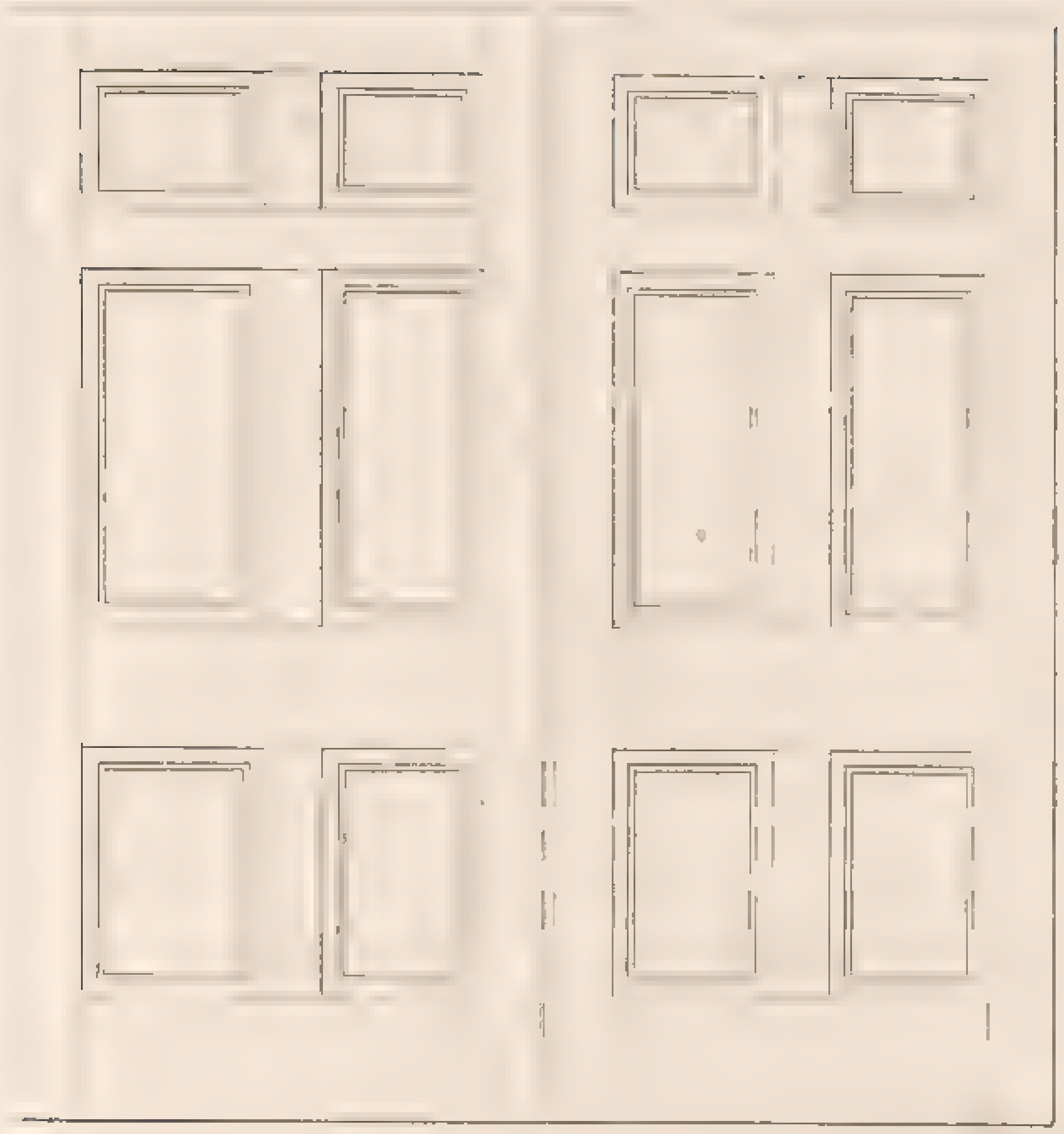


*Fig. 5.*

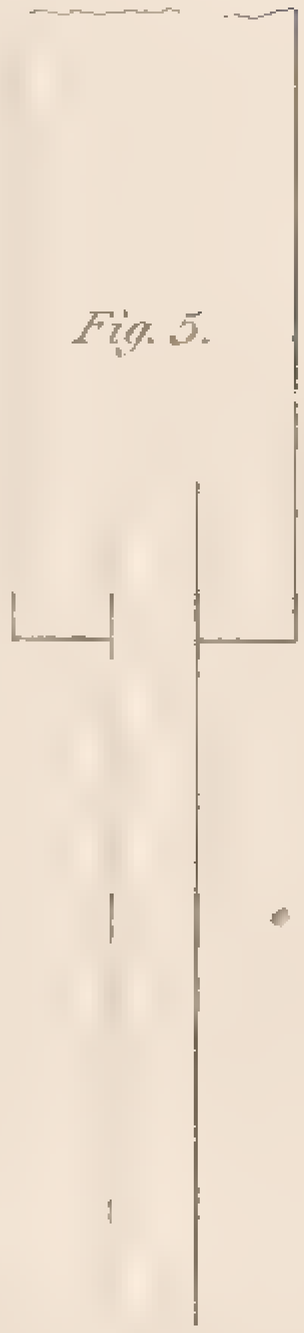


*Fig. 1*

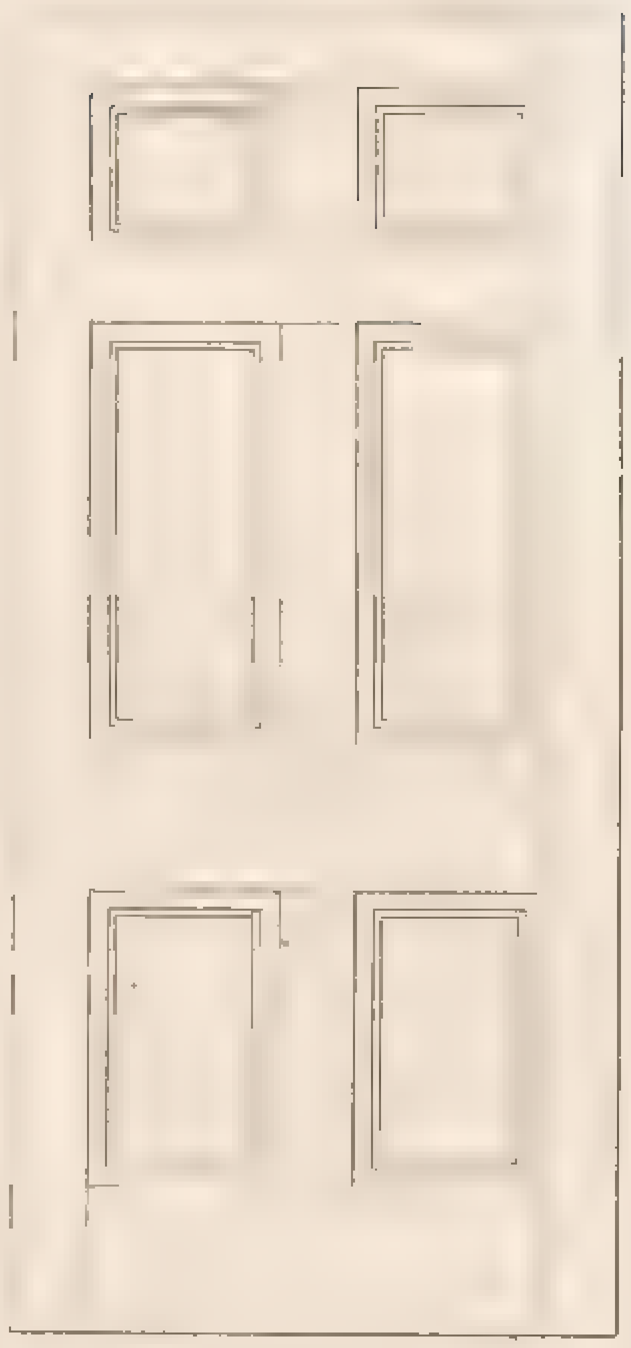


*Fig. 8.*

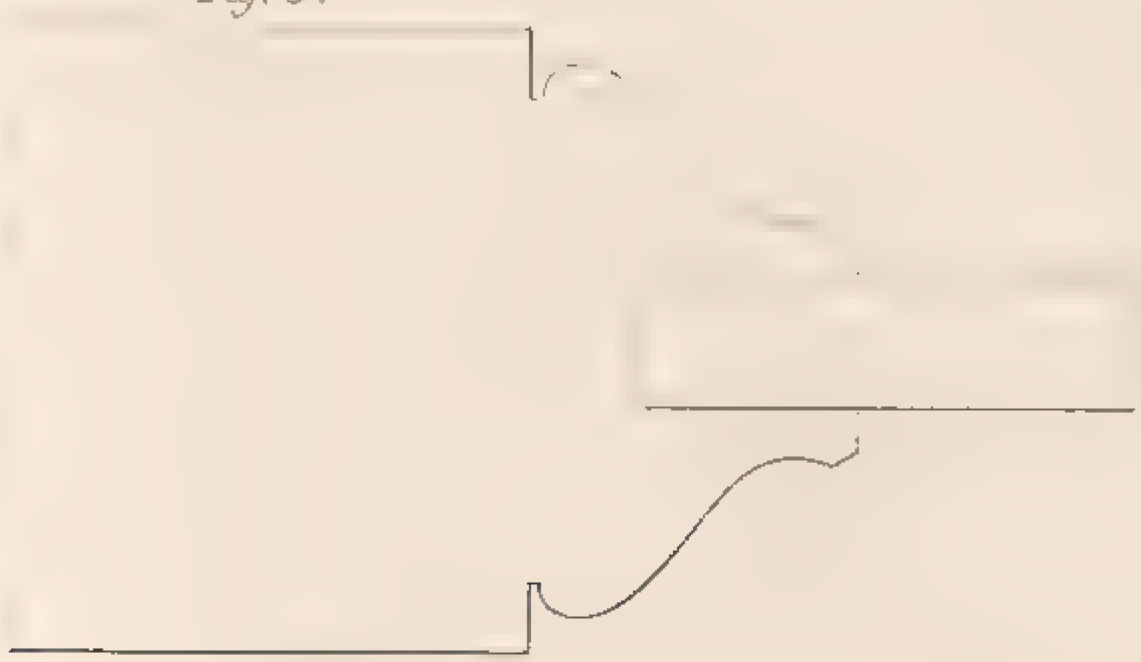


*Fig. 4.*

*Fig. 3.*

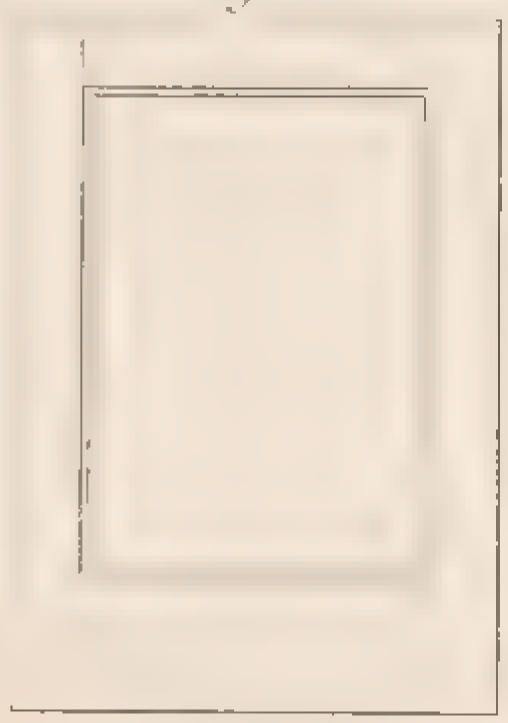


*Fig. 7*

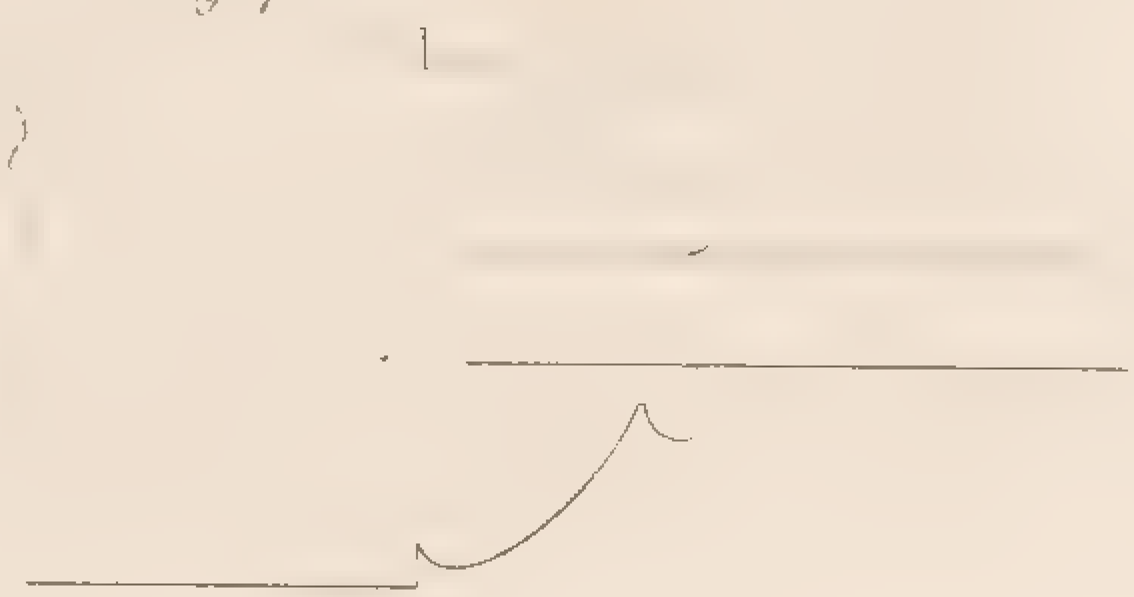
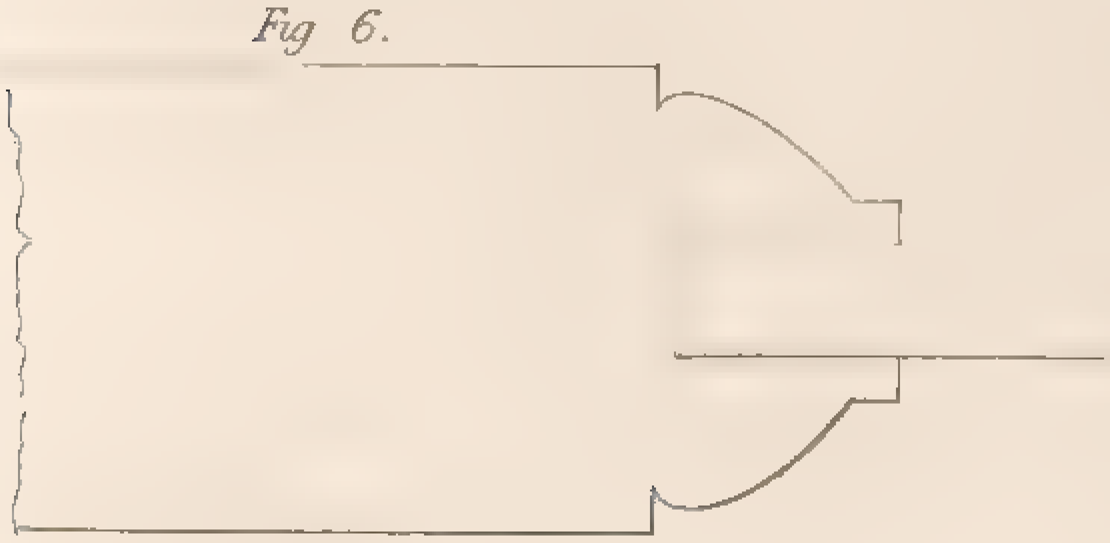


*Fig 6.*



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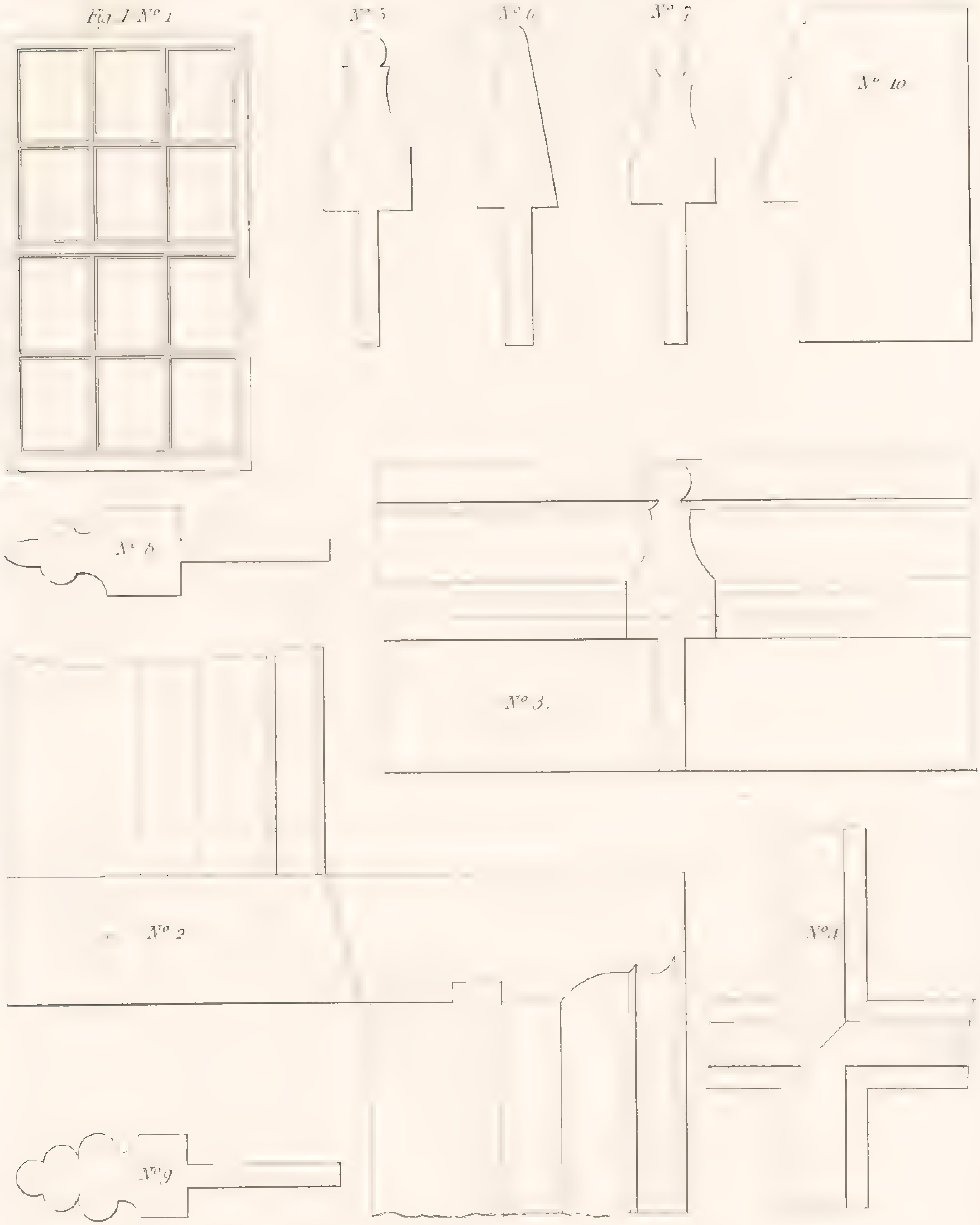
# WINDOWS.

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# BASES AND SURBASES.


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# ARCHITRAVES AND PILASTERS.


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## OF WINDOWS. (*Pl.* XXXIII.)

*Figure* 1, No. 1, the elevation of a window.

No. 2, section of the meeting bars, with a small portion of the stiles fixed to each.

No. 3 shows the method of joining the intersecting bars, with the method of doweling them together.

No. 4, the elevation of the intersection; showing part of each branch or bar.

No. 5, the section of one of the bars, being *astragal* and hollow.

No. 6, a plane diminished bar for shop-fronts.

No. 7, section of a bar with a Gothic point, instead of an astragal.

No. 8, section of a Gothic bar.

No. 9, section of a clustered bar, with two reeds on each side of the centre.

No. 10, section of the stile of the sash-frame, with the astragal and hollow mouldings.

## BASES AND SURBASES FOR ROOMS. (*Pl.* XXXIV.)

Nos. 1, 2, 3, and 4, are all sections of SURBASE-MOULDINGS, differently designed.

Nos. 5, 6, 7, and 8, are four different designs for BASE-MOULDINGS.

## ARCHITRAVES AND PILASTERS. (*Pl.* XXXV.)

Nos. 1, 2, 3, 4, 5, 6, 7, 8, are sections for different designs of ARCHITRAVES.

Nos. 9, 10, 11, 12, 13, 14, and 15, sections for different designs of PILASTERS.

## DIMINUTION OF COLUMNS. (*Pl.* XXXVI.)

To *diminish a column* is to give such a form to the surface, that the sections through the axis will all form convex curves on their edges.

To DIMINISH THE SHAFT OF A COLUMN, as in *fig.* 1.—Draw the line representing the axis, on which set off the height of the column; then, from any point in the continuation of this line, at the bottom, describe a semi-circle, of a radius equal to that of the bottom of the column, and let the diameter of this semi-circle be perpendicular to the line of the axis. Through each extremity of the axis, draw the diameter of the shaft, at the top and bottom of the column. Through one extremity of the diameter of the top of the column draw a line parallel to the axis, to meet the circumference of the semi-circle. Divide the portion of the arc, between the point of section and the diameter, into any convenient number of equal parts; the more, the truer the result will be. Divide the height, or axis, of the column into as many equal parts as those contained in the arc of the semi-circle; and through the points of division, both in the semi-circle and in the axis, draw lines perpendicular to that axis. Through each point, beginning at the bottom of the arc, draw a line, parallel to the axis of the column, to meet its respective diameter; then, through all the points of section, draw a curve, which will form the contour of the shaft, or a section of the column through its axis.

In *figure* 2, instead of dividing the arc into equal parts, divide the distance intercepted on the axis and on the radius of the semi-circle into equal parts, and proceed as in *fig.* 1.

To DRAW THE FLUTES OF A COLUMN, as in *fig.* 3.—Draw a semi-circle and the axis of a column, as before. Divide the arc of the semi-circle into as many equal parts as it is to contain flutes; and, because the number of flutes are twenty, and the middle of a flute in the middle of the elevation of

# DIMINISHING COLUMNS.


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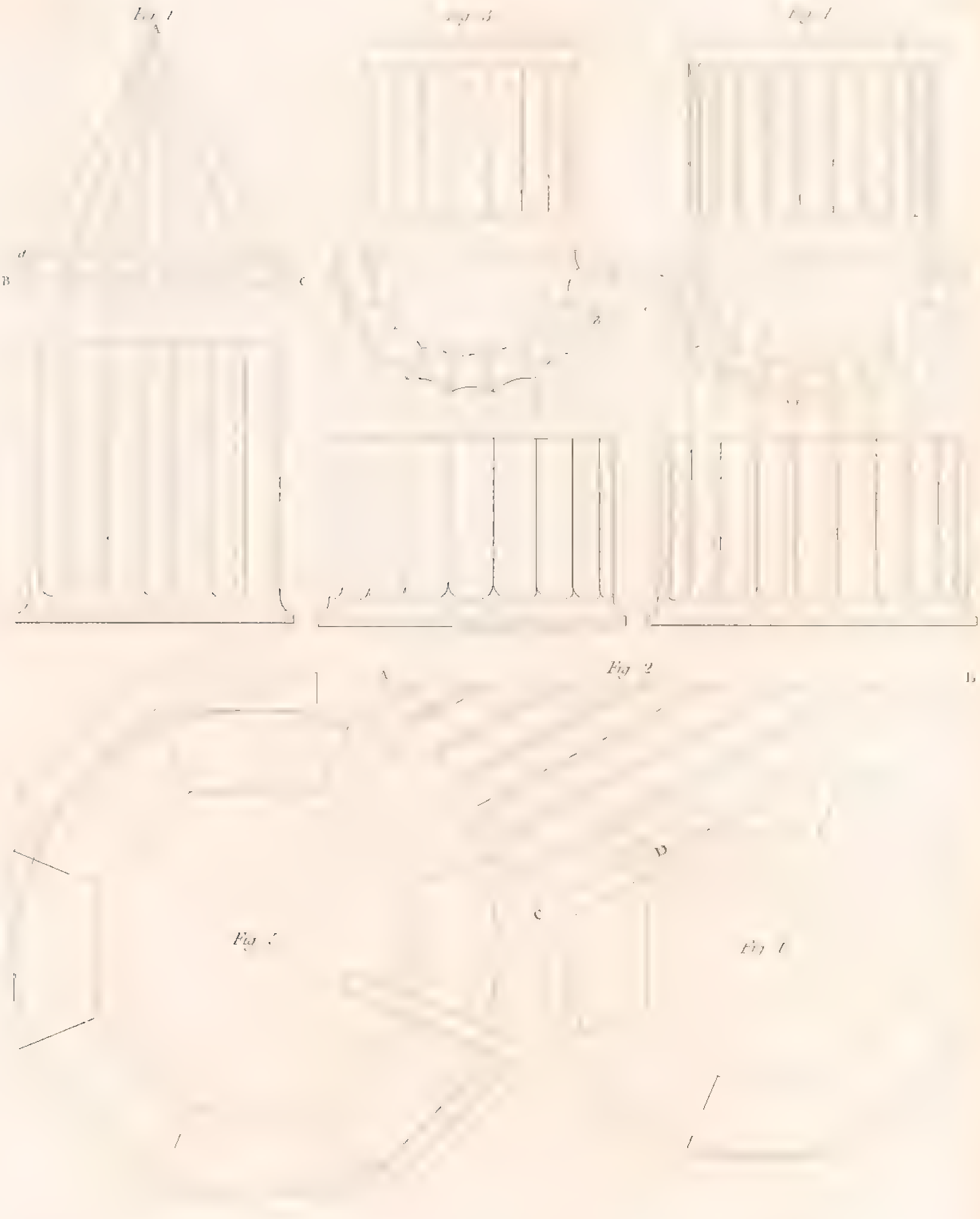
# FLUTINGS OF COLUMNS AND PILASTERS.



the shaft, the semi-circle is divided into ten equal parts, and half a part, at the extremity of the diameter. Then, having found the diameters at the different heights of the shaft, as in *fig.* 1, on the lower diameter describe an equilateral triangle. Draw lines through each point of division in the semi-circle, parallel to the axis, to cut the base of the equilateral triangle. From the points of section in the base, draw lines to the vertex. Apply each diameter from the vertex, on the side of the equilateral triangle, and mark the extremity of that side. Through each point of section, on the side, draw lines parallel to the base; and these lines will give the divisions of the flutes, which, being placed on the lines passing through the axis of the shaft, will give the points through which the flutes are to be drawn.

In the corresponding points stick in pins, or nails, and bend a pliable slip of wood round the nails, which will form the curve-line of one side of a flute: do the same for all the remaining sets of points, and we shall obtain the representation of the flutes required. The representation of the shaft thus fluted is shown in *fig.* 4.

*Figure* 5 exhibits the *diminishing rule,* which is to be applied to the side of the shaft, in order to form the curve of the surface of the shaft, as required.

## ON THE METHOD OF SETTING-OUT THE FLUTES AND FILLETS OF PILASTERS AND COLUMNS. (*Pl.* XXXVII.)

To SET OUT the FLUTES and FILLETS of a PILASTER; *figure* 1.—Let us now suppose that the breadth of a flute is to that of a fillet as four to one; and, that the breadth of the fillet, at the corner, is double to one of the intermediate fillets, or half the breadth of one of the flutes.

In the line BC, set off any convenient distance; set another interval, double of that distance; then the next part equal to half: repeat the intervals, so that an interval of one may be between every two intervals of

four; and that the intervals of four may be seven in number, and the intervals of one six in number; and that there may be an interval of two upon each extreme.

Then, with the distance BC, containing all the intervals, describe an equilateral triangle ABC. Draw lines to A from every point of division in BC. Now, it being understood that the distance BC is not less than the breadth of the pilaster to be divided; therefore, on each of the sides of the equilateral triangle, make A*d* and A*e* equal to the breadth of the pilaster, and draw the line *de*; then will *de* be equal to the breadth of the pilaster, and will be divided into the number of flutes and fillets required.

Nothing farther is necessary than to lay the parts of the line thus divided upon the edge of a rod; and thus the divisions may be transferred to each end of the pilaster.

*Figure* 2 exhibits ANOTHER METHOD of DIVIDING the FLUTES and FILLETS of a PILASTER. The parts being placed on the line AB, in the manner before described, draw BC at any angle, so that the distance between the point A and the line BC may be less than the breadth of the pilaster. Through all the points of section in AB, draw lines parallel to BC: then take the breadth of the pilaster, with a rod or compasses; and with that distance, as a radius, describe an arc from A, cutting the line BC in D, and draw AD: then apply AD as before.

*If the sides of the pilaster are convex,* the several breadths must be taken equi-distantly throughout its length, and the divisions applied to the lines in the breadth of the pilaster at each part.

The flutes and fillets may be transferred to different circles, taken equi-distantly on the surface of a column, in the same manner; but, instead of applying the parts upon a rod, they must be applied upon as many slips of parchment as the number of circumferences taken in the height of the column. But, in order to regulate the flutes, so that their edges may be all in planes passing through the axis of the column, draw a line on the surface of the column, so as to form the edge of a flute or fillet, or the middle of a flute or fillet; then one of the ends of the slip may be applied to the line

where each circle intersects it, and the slip itself stretched round the circumference till the other end meets the line again; then mark the divisions of the flutes and fillets on the circumference of the column. Through every row of equi-distant points, on the circumference of the column, from the line previously drawn, draw a line, which will be the line of demarcation of a flute and fillet.

*Figure* 3 shows the METHOD of DRAWING the FLUTES and FILLETS of a DORIC COLUMN. One particular to be observed in this, is, that a plane, passing through the axis of the column, must pass through the middle of a flute, when that plane is perpendicular to the front, and when it is parallel to the front.

The whole circumference of the Doric column is generally divided into twenty equal parts, by the arrises of the flutes, which terminate upon each other, without the intervention of fillets.

*Figure* 4 shows the METHOD of DESCRIBING the FLUTES and FILLETS on the shaft of the IONIC, CORINTHIAN, and COMPOSITE COLUMNS: and here we must observe that, as in the Doric, a plane passing through the axis, perpendicular to the front, in which the column stands, generally passes through the middle of a flute; and, that a plane, passing through the axis, parallel to the front, passes also through the middle of a flute.

The number of flutes and fillets in the Ionic, Corinthian, and Composite orders, are generally twenty-four each; the fillet being about one-fifth part of the breadth of a flute.

*Figures* 5 and 6 show the METHOD of GLUING UP the SHAFT of a COLUMN in *staves*. The number may be more as the diameter of the column is greater. In the example before us, the number of staves is eight; therefore we must describe circles, one to the diameter of the top, and another to the diameter of the bottom, of the column, and circumscribe an octagon round each circle; then draw another octagon, of which the sides are parallel to those of the octagon already drawn; so that the distance of the parallel sides of the octagons may be equal to the proper thickness of stuff required to make the

shaft of the column. From the angles of the octagon draw lines to the centre, which will give the directions of the joints; but, though the angle shown by the bevel in *fig.* 5, would not differ sensibly from the truth, the proper method to find it is the same as finding the backing of a hip-rafter; and, if the outside of the column is curved, it will be eligible to apply the bevel from the inside; because, if applied to the convex side of the column, every different place would require a different angle.

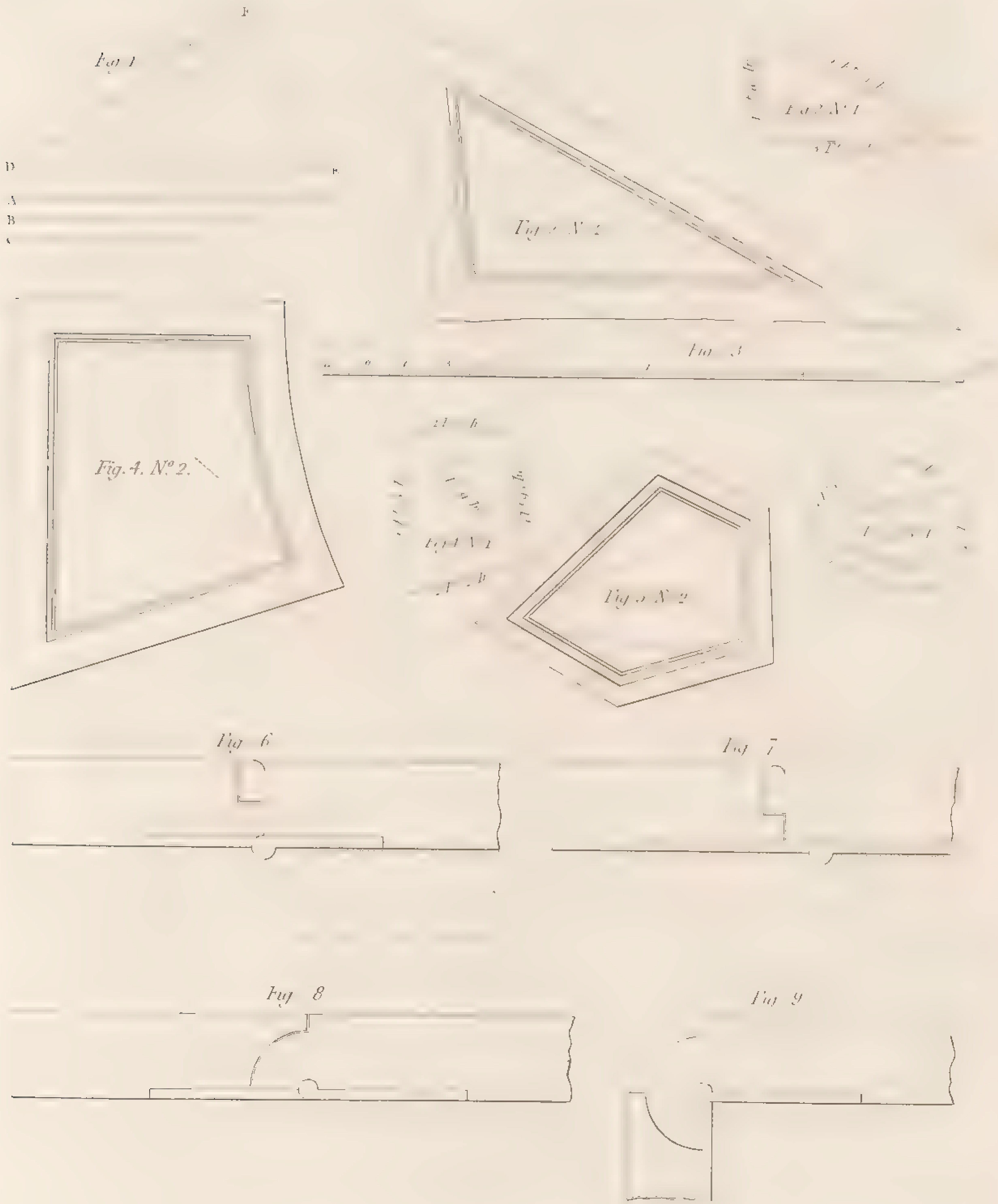
## METHODS OF TAKING DIMENSIONS AND HINGEING.

The taking of dimensions depends upon the method of describing a triangle, from the three sides being given: therefore, let ABC, (*fig.* 1, *pl.* XXXVIII,) be the three given sides of a triangle: draw the straight line A in any convenient place, as DE: from D, with the straight line B, as a radius, describe an arc at F; and, from E, with the straight line C, as a radius, describe another arc, cutting the former in F; join DF and FE: then will DEF be the triangle required.

In order to take the dimensions of a place which is to receive a piece of framing, make an eye-draught, as in *fig.* 2, No. 1; and upon each line mark the dimensions of the sides; then take the lengths of these sides from the scale, *fig.* 3, and find the angular points of the triangle, No. 2: having cut each piece of stuff to its proper length, scribe each edge down to its place; then lay together the ends which are to meet, one piece being on the top of the other, and draw the shoulders of the joints.

When the place which is to receive the framing consists of more than three sides, sketch the figure, as before; draw lines from one corner to every other corner, and mark the dimensions upon these lines, and the dimensions of each side of the figure upon its respective line. This is fully exemplified in *figures* 4 and 5, taken from the same scale.

# THE METHOD OF TAKING DIMENSIONS AND HINGEING.



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London, Published by Thos. Kelly, 17, Paternoster Row, Jan. 1, 1822.

# HINGEING DOORS AND SHUTTERS.


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*Figure* 6 exhibits the METHOD OF HINGEING ONE FLAP TO ANOTHER, the joint being what may be termed a *lap-joint.* The centre of the hinge is placed opposite to the joint.

*When one flap revolves upon another,* it is sometimes required to throw the edge of the flap, when folded close upon the back of the other, at a given distance: to do this, the centre of the hinge must be placed at half that distance from the joint: this is exemplified in *fig.* 7.

*Figure* 8 shows the METHOD OF HINGEING A RULE-JOINT, the axis of the hinge being in the axis of the cylindric surface that forms the rule-joint.

*Figure* 9 shows one of the flaps folded upon the other.

This method is sometimes used in window-shutters, though mostly in furniture.

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## HINGEING DOORS AND SHUTTERS. (*Pl.* XXXIX.)

*Figure* 1, Nos. 1 and 2, represents the form of the joint of two stiles, in order to fit each other. No. 3 shows the same when hinged together.

*Figure* 2, Nos. 1 and 2, exhibits a plane-joint, beaded alike on both sides: No. 3 shows the same when hinged together.

*Figure* 3, Nos. 1. and 2, exhibits the same thing with a double-lapped joint. No. 3 shows the two parts put together.

*Figure* 4, Nos. 1 and 2, shows the same thing, with a single-lapped joint.

*Figure* 5 exhibits the manner of hingeing the shutter to the sash-frame.

*Figure* 6 exhibits the manner of hanging the door upon centres.

*Figure* 7 shows the method of hingeing shutters, so as to conceal the hinges.

## MOULDINGS ON THE SPRING. (*Pl.* XL.)

*Figure* 1 is the elevation of a cylindric body. At the upper end, G and I are the profiles of a cornice, or section of a cornice, to be put round the cylindric body. If the moulding is formed from a solid piece, it must be formed in short lengths; for, if the pieces are very long, the grain will run across them, and will render the pieces weak, and make the moulding very ugly.

In order to prevent the crossing, as much as possible, the best way is to reduce it, by cutting off the right angle by a plane, as nearly parallel to the face as possible; and the moulding may be bent in the same manner as in covering the frustum of a right cone. Thus may the moulding be got out of a thin board. Bisect the breadth DF, in the point E, and draw EH parallel to FG or DI. Produce the back of the cornice, *kl*, to meet the line of axis in *m*; then, from the point *m*, as a centre, with the distances from *m* to each edge of the fillets and moulding, describe arcs, and these will represent the lines for working the mouldings on the board.

*Figure* 2 shows the method of describing the mouldings when put round the segment of a cylinder. Here the whole semi-circle must be completed, and the moulding placed as before, and described after the same manner.

*Figure* 3 exhibits the method of describing the moulding for the interior surface of a cylinder.

*Figure* 4, the section of a base moulding, to be bent on the spring.

*Figure* 5, a cornice, where the mouldings are almost in a straight line. This is well adapted for the surface of a cylindric body.

*Figure* 6 is the profile of a cornice, where the cyma-recta only is intended to be sprung. Here this part must be bracketed behind, in order to keep it firmly in its place. The corona and the bed-moulding are made of a solid piece.

# MOULDINGS ON THE SPRING.


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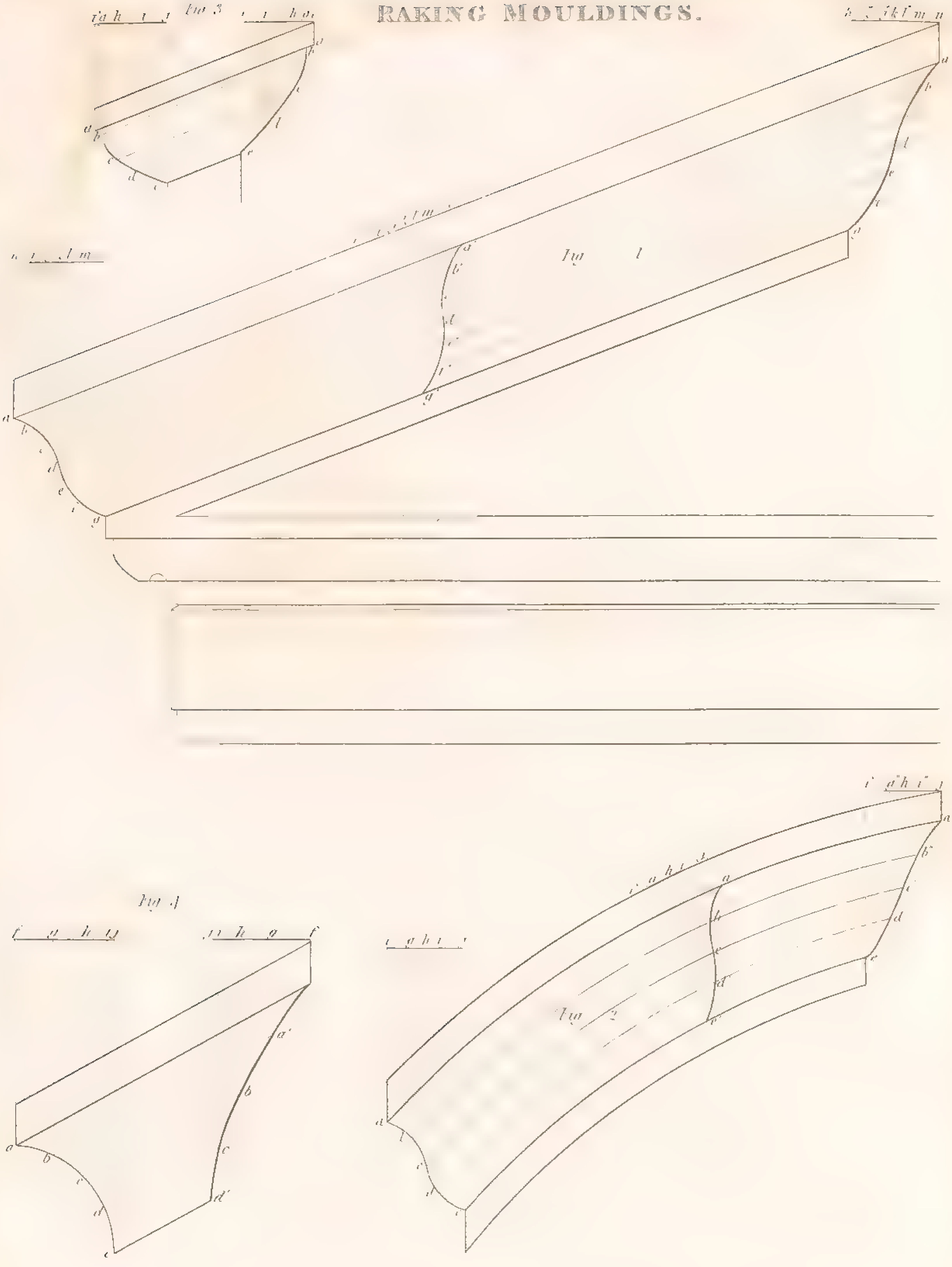
# RAKING MOULDINGS.



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# RAKING MOULDINGS.

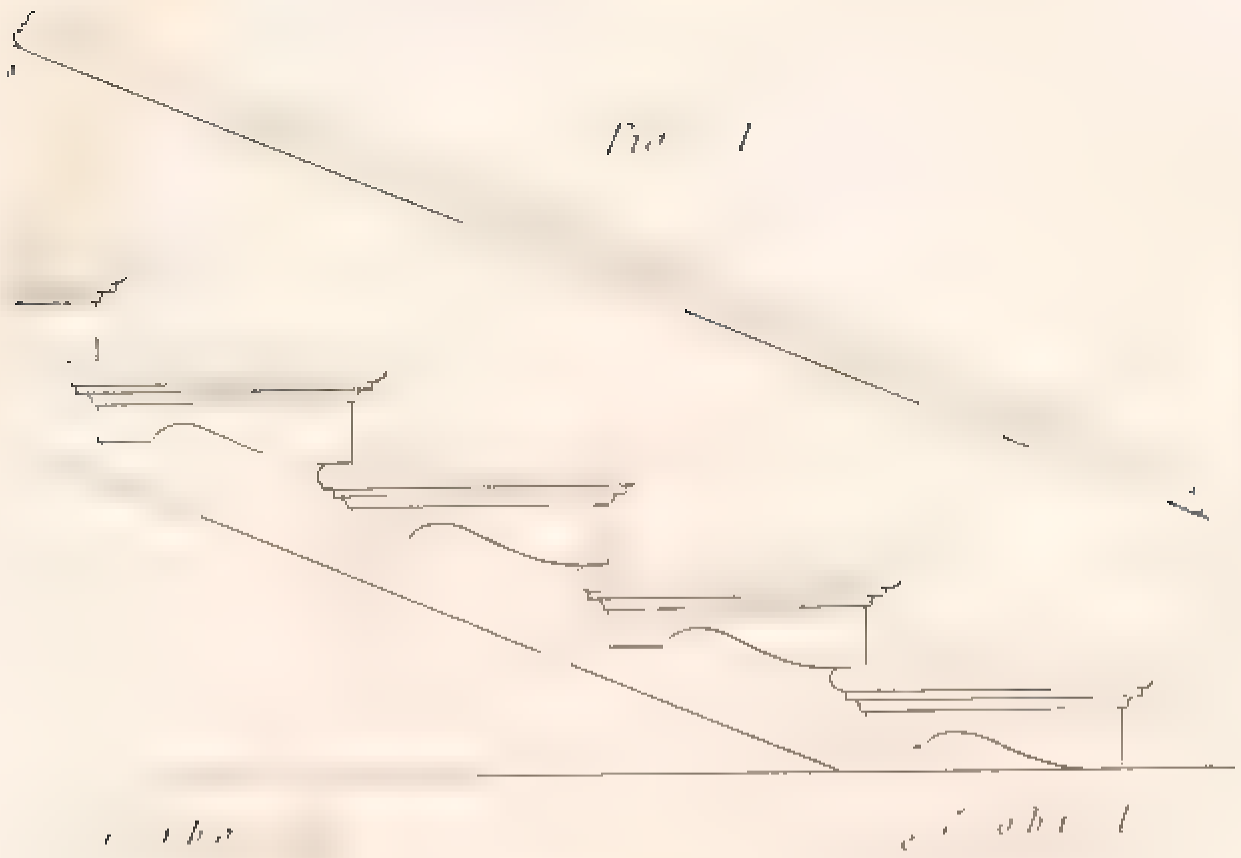

Fig. 1.

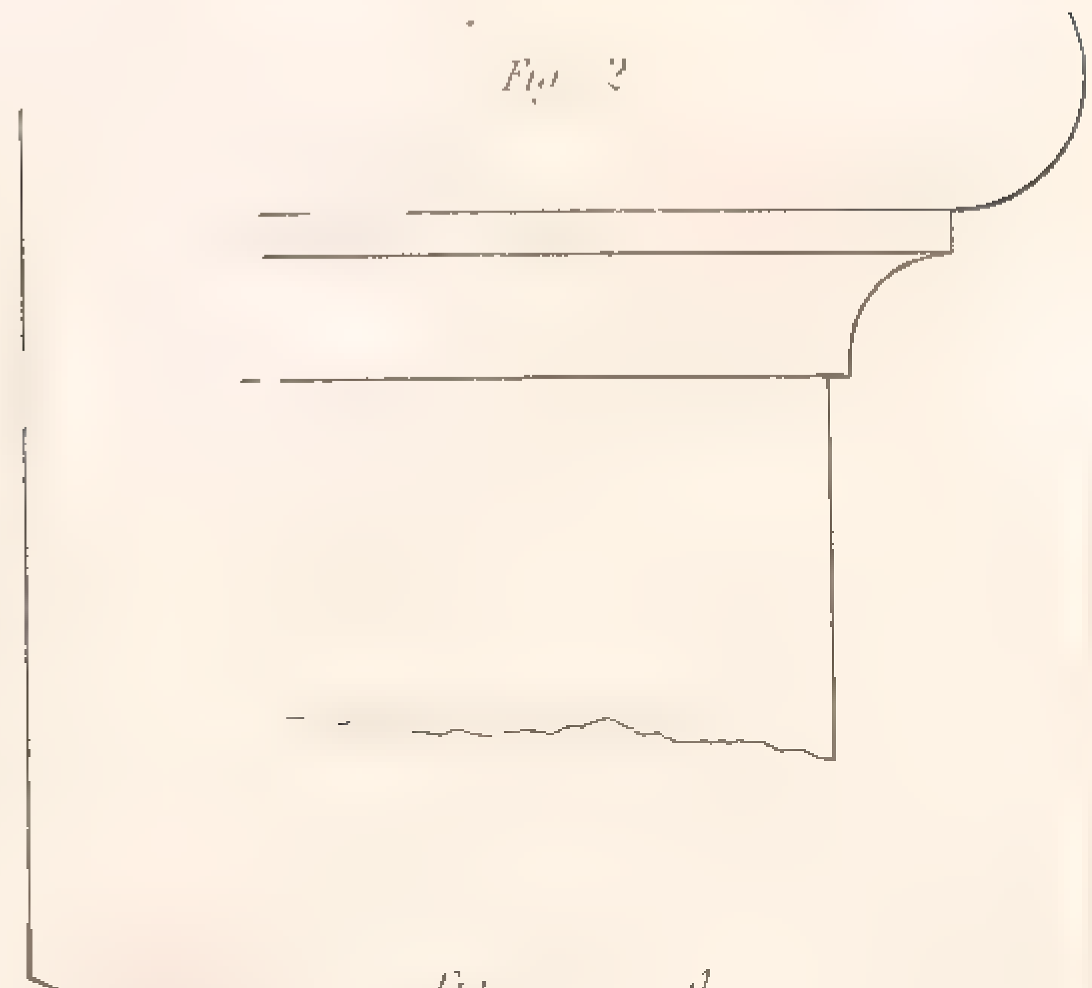

Fig. 2.

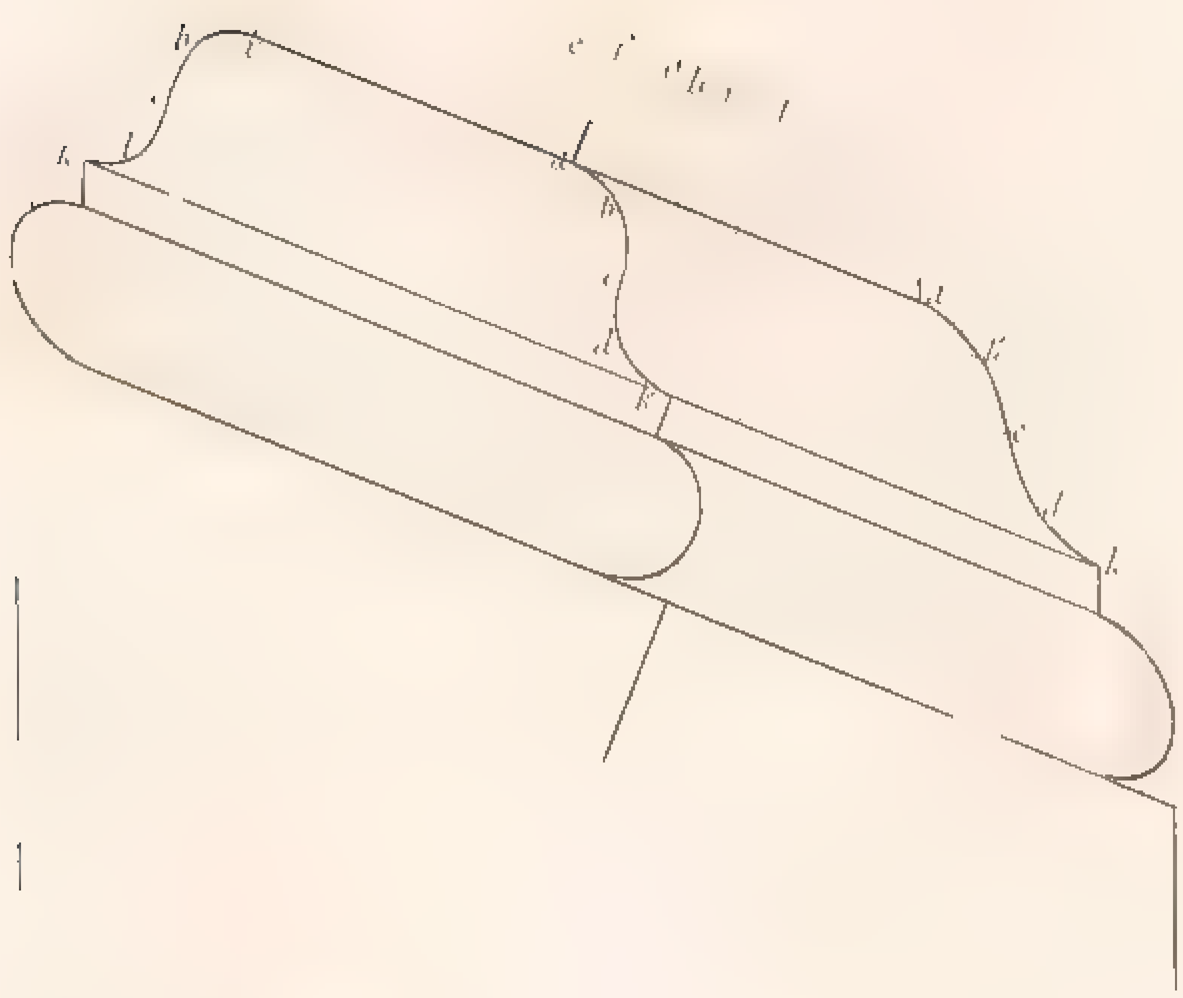

Fig. 3.

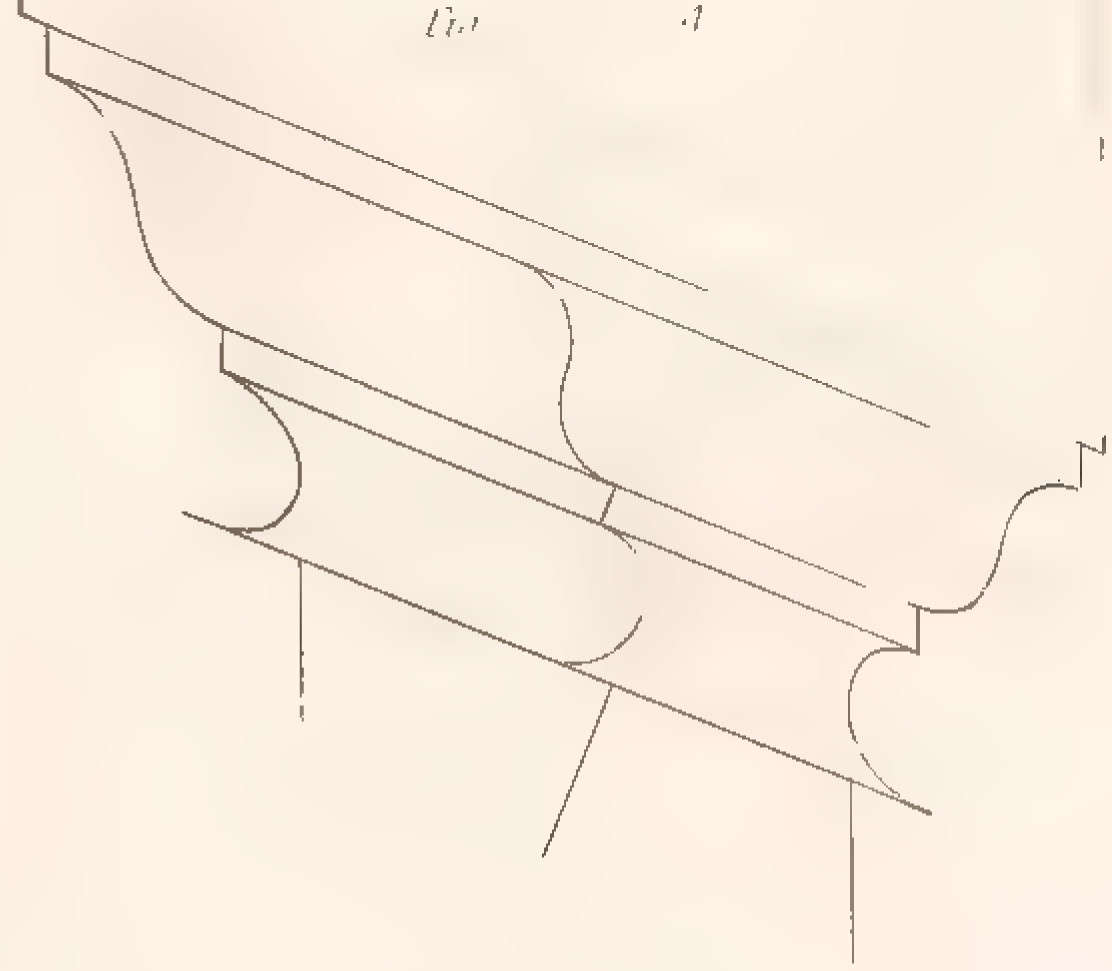

Fig. 4.

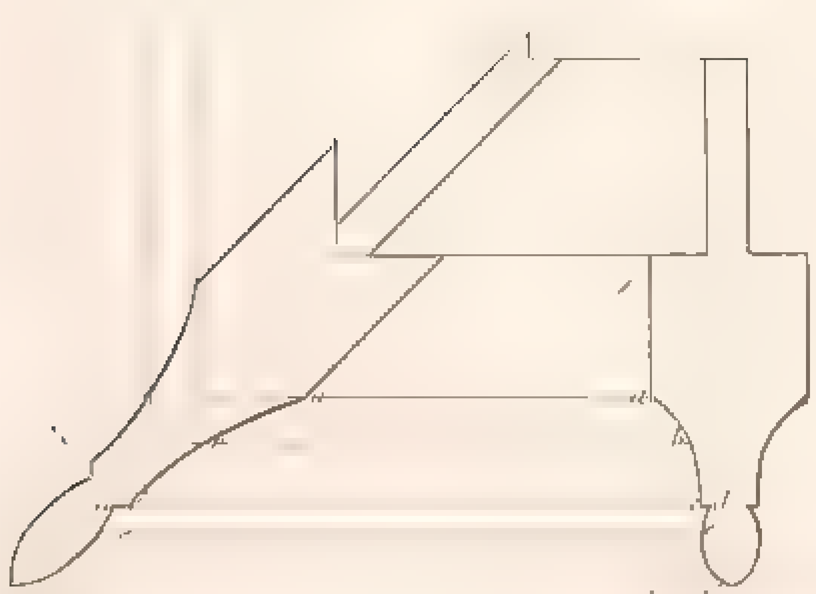

Fig. 5.

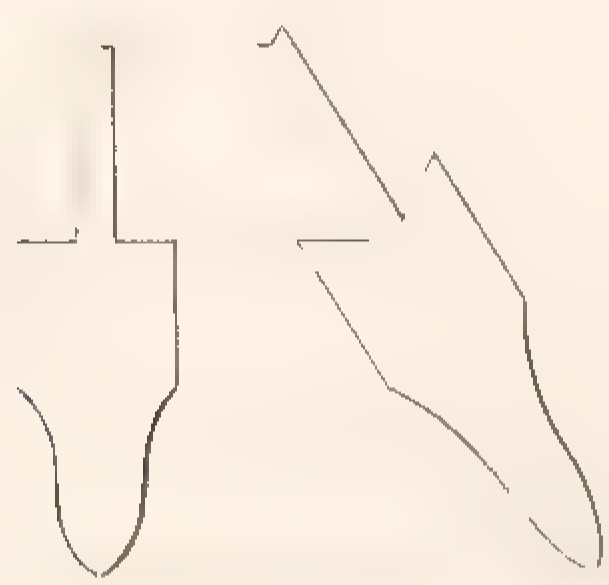

Fig. 6.

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## RAKING MOULDINGS. (*Pl.* XLI.)

When a building has a pediment, with mouldings or a horizontal cornice, crowning the walls, and a pediment, with a similar cornice, upon the rake, the upper mouldings are mitred together, so that the mitre-plane may be perpendicular to the horizon: this renders the sections of the upper member of the horizontal cornice, and that of the pediment, dissimilar in their right section: the question then is, having the section of the one, how to find the section of the other. But, since the horizontal cornices are generally wrought first, the section of the horizontal moulding at the top is given, in order to find that of the pediment.

Therefore, in *fig.* 1, there is given the horizontal section, $abcdefg$, to find the section of the inclined moulding. Let the points $a, b, c, d, e, f, g$, be any number of points taken at pleasure; draw lines through these points, parallel to the rake; and, also, draw lines through the same points, perpendicular to the horizontal cornice, so that all shall cut any horizontal line in the points $h, i, j, k, l, m, n$. Transfer the distances between the points $h, i, j, k, l, m, n$, any where upon the raking line, to $h', i', j', k', l', m', n'$; and, from these points, draw lines perpendicular to the rake, cutting the inclined lines at the points $a', b', c', d', e', f', g'$; then, through the points $a', b', c', d', e', f', g'$, draw a curve, which will be the section of the inclined moulding.

Again, suppose it were required to return the moulding upon the rake to a level moulding at the top: Upon any horizontal line, transfer the distances between the points $h, i, j, k, l, m, n$, to $h'', i'', j'', k'', l'', m'', n''$; and, from these points, draw lines perpendicular to the level cornice, cutting the raking-lines before drawn at the points $a'', b'', c'', d'', e'', f'', g''$; then, through the points $a'', b'', c'', d'', e'', f'', g''$, draw a curve, which will form the return-moulding at the top.

*Figure* 2.—The lower section is the horizontal part, and the upper section is that of the upper return-moulding, found in a similar manner to *fig.* 1, excepting that, as the mouldings themselves are circular, the lines drawn through the points *b, c, d,* must also be circular; and, instead of laying the parts between the points, *b, c, d,* &c., upon the raking-line, they must be laid upon a straight line, which is a tangent to the circle.

*Figure* 3 shows the method of finding the return mouldings for a *raking ovolo;* the lower section being the given moulding, and the upper one that of the return horizontal moulding.

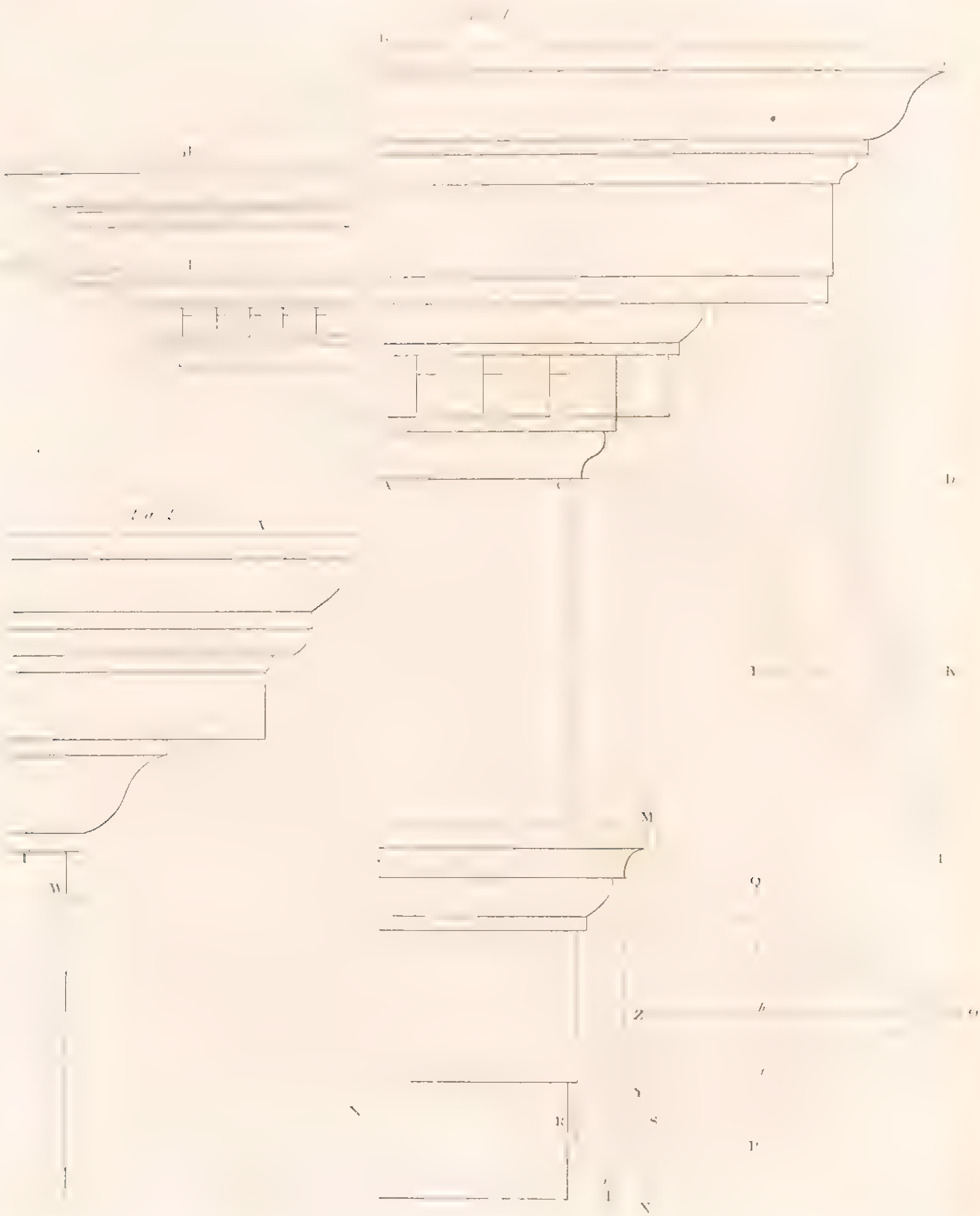
*Figure* 4 exhibits the method of finding the return of a *raking cavetto.*

Plate XLII, *fig.* 1, shows the steps of a stair, where the base-moulding continues along the rake, and returns both at the bottom and top of the stair. *Figure* 2 exhibits the moulding upon the nosing: *fig.* 3, the raking-mouldings, found as in *fig.* 1, *pl.* XLI. *Figure* 4 shows the same thing, when the mouldings are to be placed around an internal space.

*Figure* 5 represents raking-mouldings for angle-bars of shop-fronts: *abcd,* &c., is the given moulding. Take any number of points, *a, b, c, d,* &c., in the curve, and draw lines, $aa'$, $bb'$, $cc'$, $dd'$, &c., parallel to the face of the window; draw a line perpendicular to the mitre line; then, through the points *a, b, c, d,* &c., draw lines perpendicular to the line of the face of the window, cutting it at the points *e, f, g, h, i.* Transfer the distances between the points *e, f, g, h, i,* upon the line which is drawn perpendicular to the mitre-line, at $e'$, $f'$, $g'$, $h'$, $i'$; then draw lines parallel to the mitre-line, cutting the lines drawn parallel to the front at the points $a'$, $b'$, $c'$, $d'$, &c., and, through the points, $a'$, $b'$, $c'$, $d'$, &c. draw a curve, and it will form one side of the angle-bar: then, making the other similar, the whole angle-bar will be formed.

*Figure* 6 shows another design of a bar, where the window returns at an obtuse angle. The method of forming the angle-bar is the same as in *fig.* 5.

# METHOD of ENLARGING and DIMINISHING MOULDINGS.

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## METHOD OF ENLARGING AND DIMINISHING MOULDINGS. (*Pl.* XLIII.)

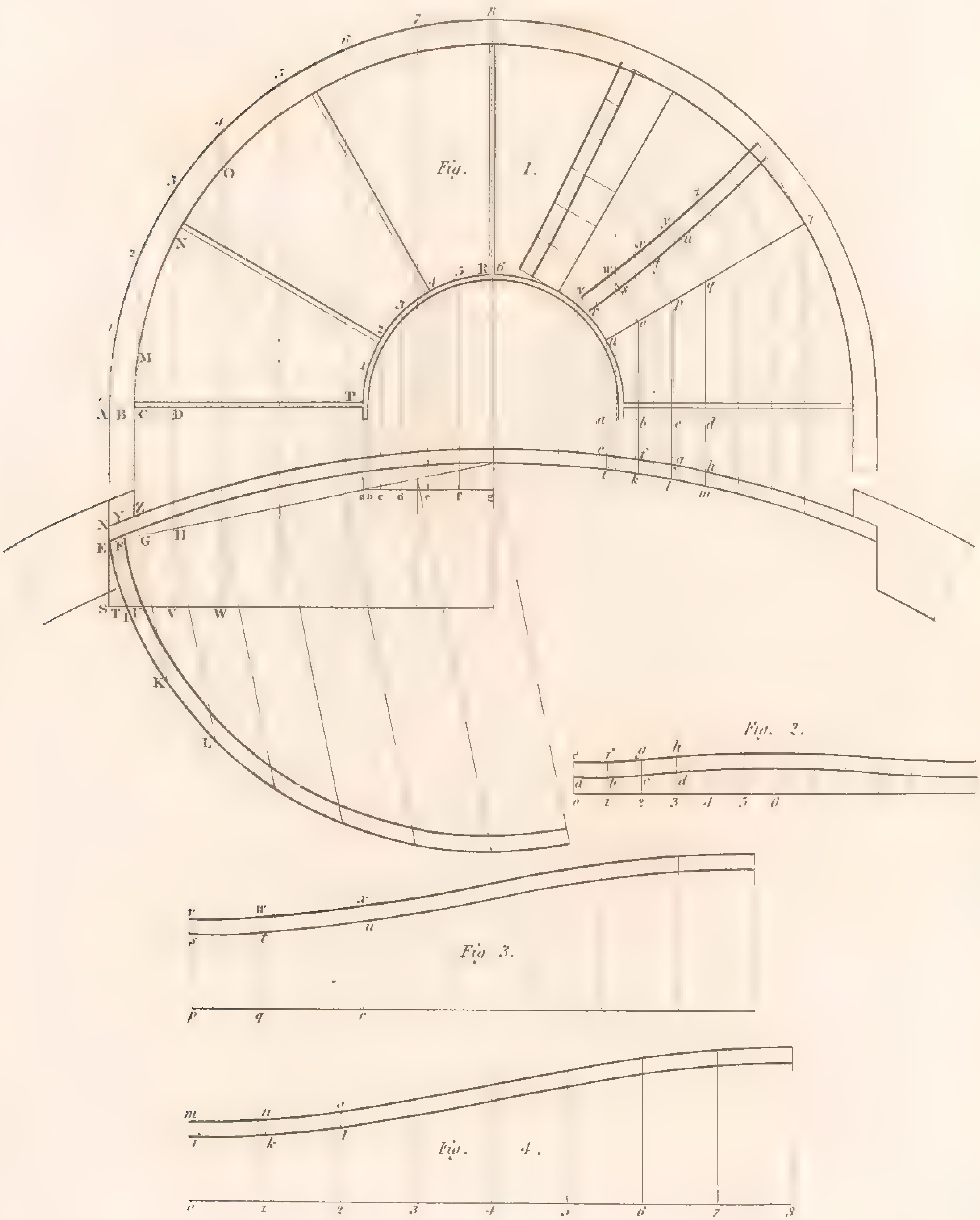
This depends entirely on the proportion which any two lines, of different lengths, have to one another, when divided in the same ratio. Euclid proves, and indeed it is self-evident, that, if a line be drawn parallel to one side of a triangle, and if lines be drawn from the opposite angle, through any number of points taken in one of the parallels, to cut the other, these two parallels will be divided in the same ratio. This is one of the principles of proportioning cornices. Another method of proportion, emanating from a similar principle, proved by the same geometrician, and which is equally evident, is, when any number of straight lines are drawn parallel to one side of a triangle, so as to cut each of the other two sides in as many points, each of the two sides thus divided have their corresponding segments in the same proportion. Hence we have only to construct a triangle, which shall have two of its sides given; for, if the divisions in one of these lines be given, we may divide the other in the same ratio, by drawing lines parallel to the third side of the triangle: or, according to the first principle, if a straight line be drawn parallel to one side of a triangle, this straight line will divide the triangle into two similar triangles; therefore, if the triangle to be divided be equilateral, the smaller triangle, when divided, will also be equilateral. Therefore, if the divided line be greater than the undivided line, we have only to construct an equilateral triangle, and set the length of the undivided line from one of the angular points upon one of the sides, and draw a straight line through the point of extension, parallel to the side opposite to that angular point; then, placing the parts of the divided line on the greatest of the two parallel lines, we have only to draw lines, through the points of division, to the opposite angle, and the lesser parallel line will be divided in the same proportion.

Let AB, (*fig.* 1, *pl.* XLIII,) be the height of a cornice, divided by the height of the members into as many segments. Upon AB describe the equilateral triangle ABE; from the points of division in AB draw lines to E. On the side EB or EA, of the triangle, make EH or EG equal to the height of the intended cornice, and draw GH parallel to AB; then GH will contain the heights of the members of the new cornice. The projections are found thus: AC, being the lower line of the cornice, produce AC to D; and, from all the points of projecture, draw lines perpendicular to CD, cutting CD in as many points as the lines thus drawn. The point D, being the extreme projecture, produce the line downwards from D to F, and make DF equal to the perpendicular of the equilateral triangle AEB. Draw lines from the divisions in CD to the point F. Make FK equal to the perpendicular EI, as terminated by the line HG, and draw KL parallel to CD, cutting all the lines drawn from the points of division in CD; then KL will contain the projectures of the new cornice, of which the height is GH: and thus, having the heights and projectures of the members of the new cornice, it may be drawn by the usual rules.

The mouldings of the architrave are proportioned in the same manner. Thus, describing an equilateral triangle MNO; on the height, MN, of the architrave, produce the lines of division in the height to meet the line MN; from the points of division in MN draw lines to O, the apex. Make OQ equal to the height of the new or intended architrave, and draw PQ parallel to MN, and PQ will be divided in the same proportion as MN. To find the projectures, draw RS perpendicular to MN, and describe the equilateral triangle RST. From the points of projecture, in the lines dividing the height, draw lines parallel to MN, cutting RS, the side of the equilateral triangle. Draw lines from the divisions in RS to the opposite angle T. Any where in the line MN make YZ equal to the side RS of the equilateral triangle, and draw YO and ZO, cutting PQ in *a* and *b*. On the side TS, of the small equilateral triangle, make T*c* equal to *ab*, and draw *cd* parallel to RS; then *cd* will be divided in the same proportion as RS.

To Enlarge a Cornice, according to any given height: *Figure* 2. From any point, V, with a radius equal to the intended height of the cornice,

# CONSTRUCTION OF CIRCULAR SASHES.

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London, Published by Thos. Kelly, 17 Paternoster Row, January 1, 1822.

describe an arc cutting the opposite edge in U; and the line VU, being drawn, will contain the heights of the members of the new cornice.

*To find the Projections.*—Draw any line, WX, perpendicular to UV, between the extreme vertical lines of projecture; and, from all the extreme points of projecture, draw verticals to cut the line WX, which will be divided into the proper projectures.

## CONSTRUCTION OF CIRCULAR SASHES IN CIRCULAR WALLS. (*Pl.* XLIV.)

To form the Cot-bar of the Sash-frame.—*Figure* 1 is an elevation of the window. Divide the half arc of the cot-bar, PR, into any number of equal parts, as six; and, from the points of division, draw perpendiculars to the horizontal line ag; transfer the parts of the horizontal line *ab, bc, cd,* &c. to *fig.* 2, from 0 to 1; 1, 2; 2, 3; 3, 4; &c., to 6; and reverse the order from the central point 6, and draw perpendiculars upwards from these points: make the heights of the perpendiculars, *fig.* 2, to correspond to those taken from the plan, *fig.* 1. Through all the points draw curves, which will be the form of the mould for the veneers to be glued in thickness.

*To form the Head of the Sash-frame.*—Divide the elevation round the outer edge into any number of equal parts, and draw perpendiculars to the chord of the half plan. From the points where these perpendiculars intersect the chord of the half plan, draw ordinates, perpendicular to the chord of the half plan. Make the ordinates FI, GK, HL, &c. equal to B1, C2, D3, &c.; and the ordinates of the inner curve equal to CM, DN, &c.; then, through the points E, I, K, L, &c., draw a curve; and within, through the other points, draw another curve; and this will form the face-mould for the sash-head.

*Figure* 3 is the development of the soffit of the under side of the sash-head. *Figure* 4, that which is applied to the convex side of the same: so that, by

cutting away the superfluous wood on the outside of the space contained by the two lines, the sash-head will fit the surface of a cylinder made to the radius of the plan of the window.

*To find the Radial Bars.*—Let $n\gamma$, *fig.* 1, be the place of a radial bar. In $n\gamma$ take any number of points, *n, o, p, q,* &c., and draw the perpendiculars *nv, ow, px, qy,* &c., to $n\gamma$. Draw, also, *ni, ok, pl, qm,* &c., perpendicular to the base-line of the elevation, cutting the base-line at the points *a, b, c, d,* &c.; and cutting the convex side of the sash at the points *e, f, g, h,* and the concave side at *i, k, l, m,* &c. Make the distances *nv, ow, px, qy,* &c., respectively equal to *ai, bk, cl, dm,* &c.; and, through the points *v, w, x, y,* &c., draw a curve, which will form the convex edge of the radial bar. In the lines *nv, ow, px, qy,* &c., make the distances *nr, os, pt, qu,* &c., each respectively equal to *ae, bf, cg, dh,* &c.; and, through the points *r, s, t, u,* &c., draw another curve, which will give the inner edge of the radial bar.

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## OF SKYLIGHTS. (*Pl.* XLV.)

SKYLIGHTS are windows in the roofs of houses, and are necessary when light cannot be had in the sides of the room or apartment required to be lighted.

*Figure* 1, No. 1, is a portion of the Plan of a Square Skylight. No. 2, the Elevation.

*To find the Seats of the Hips.*—Bisect the angle ABC, No. 1, by the straight line BE; and bisect the angle BCD by the straight line CE: then BE and CE are the seats of the hips.

*To find the Length and Angles of the Hips.*—Draw EF perpendicular to CE, and make EF equal to the height of the skylight, and join CF; then CF is the length of the hip, ECF the angle which it makes with its seat or base, EFC the angle which it makes with the perpendicular.

# SKYLIGHTS.

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*To find the Backing of the Hips.*—From any point G, in EC, draw GL perpendicular to CF, cutting FC in L; and, through G, draw HI, perpendicular to CE, cutting BC in H, and CD in I. In CE make GK equal to GL, and join HK in IK: then will HKI be the angle required.

*Figure* 2 is the plan and elevation of an octagonal skylight. The method of finding the seats of the hips, their lengths, angles, and backing, is the very same as in the preceding example; and, therefore, any farther explanation will be unnecessary.

*Figure* 3, an octagonal skylight, cut by the inclined side of a roof. The method of drawing the curb for such a roof requires some explanation, in order to be understood. No. 1 is the *plan*, No. 2, the *elevation*, showing the part above the roof, which is exactly the same as that of a common skylight.

In No. 2, through the summit S, draw ST, parallel to the base, cutting the sloping line of the roof in T.

In No. 3 draw PQ equal to the breadth of the octagon, No. 1. Bisect PQ in U, by a perpendicular, UL. Make UL equal to RT, and join PL and QL. Through L draw KM, parallel to PQ, and make LK and LM each equal to UP or UQ. Draw PM and KQ, cutting each other in I, PL in V, and QL in W. Join VW. Make UC and UD each equal to half the side of the octagon. Draw CK, cutting PL in B, and DM, cutting QL in E. Through I draw NO, parallel to PQ, meeting CK in N, and DM in O. Draw NM, cutting BL in A, and VW in H: also, draw OK, cutting QL in F, and VW in G; then ABCDEFGHA is the outline or exterior edge of the curb. The interior edge, *abcdefgha*, is drawn by means of the same points, K, L, M, and the edges, *cd* and *hg*, parallel to CD, so as to meet each other upon the diagonals *a*I, *b*I, *c*I, *d*I, &c. This is the same as the perspective representation of the plan, by supposing the eye of the spectator fixed at S, No. 2, RT the section of the picture, and RX a section of the original plane. In this case, K, L, M, No. 3, are called the *vanishing points*; L is the centre of the *vanishing line*; PQ is what is called the *intersecting line*; PK, or QM, is the *height of the picture*; and ST, No. 2, is the *distance of the eye* from the picture.

The points K and M, No. 3, would have been ascertained in perspective, thus: Produce UL to Y, and make LY equal to ST. Now, supposing the plan, No. 1, on the other side of PQ, No. 3, with two sides of the octagon parallel to PQ, one of them may coincide with the part CD of PQ. Then, through Y draw a line YK and YM, parallel to the diagonals of the square which forms the sides of the octagon; then the points K and M are the *vanishing points.*

---

## DESIGNS FOR SHUTTING-WINDOWS. (*Pl.* XLVI.)

THE parts A, B, C, D, E, F, G, H, *fig.* 1, form a SECTION of the SASH-FRAME.

A, Pulley-stile of the sash-frame.

B, Inside Lining.

C, Outside Lining.

D, Back Lining.

E and F, Weights to balance the sash-frame.

Here the pulley-stile, A, is tongued into the inside lining, B, and into the outside lining, C. The back lining, D, laps over the edge of the outside lining, C, and is tongued into the inside lining, B.

The parts K, I, B, form a recess for receiving the shutters, which recess is called the BOXING.

I is called the back lining of the boxing, and is tongued into the inside lining of the sash-frame.

K is a ground, of which the outside is flush with the plaster. The inside lining of the boxing is also tongued into the ground K.

H, Section of the inside bead of the sash-frame.

G, Parting-bead, and serves to separate the upper from the lower sash, in order that they may work freely and independently of each other. R, architrave, or pilaster.

*Figure* 2, A VERTICAL SECTION of the WOOD-WORK of the SASH-FRAME, and the parts attached to it.

# DESIGNS FOR SHUTTING WINDOWS.

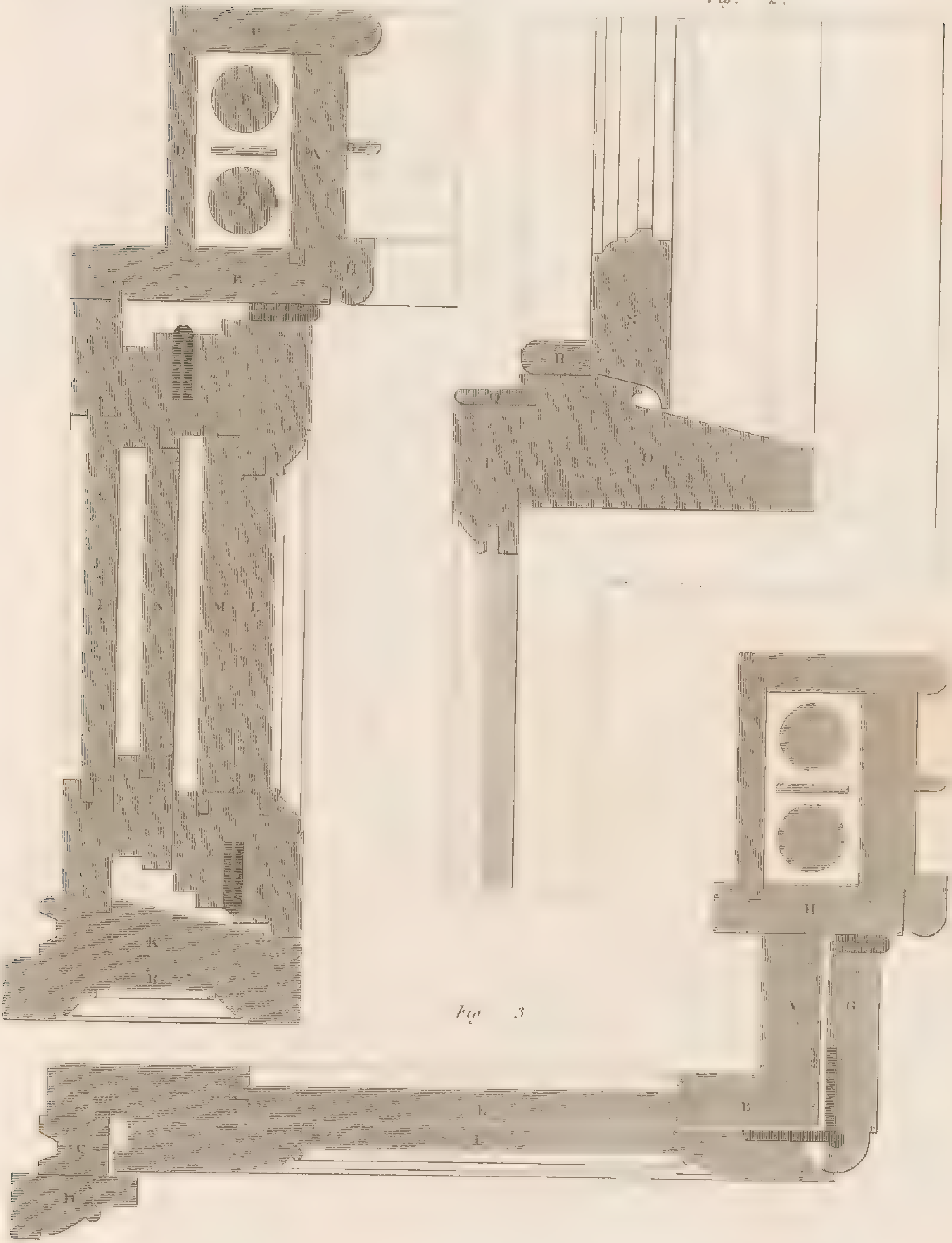

Fig. 1. Fig. 2. Fig. 3.

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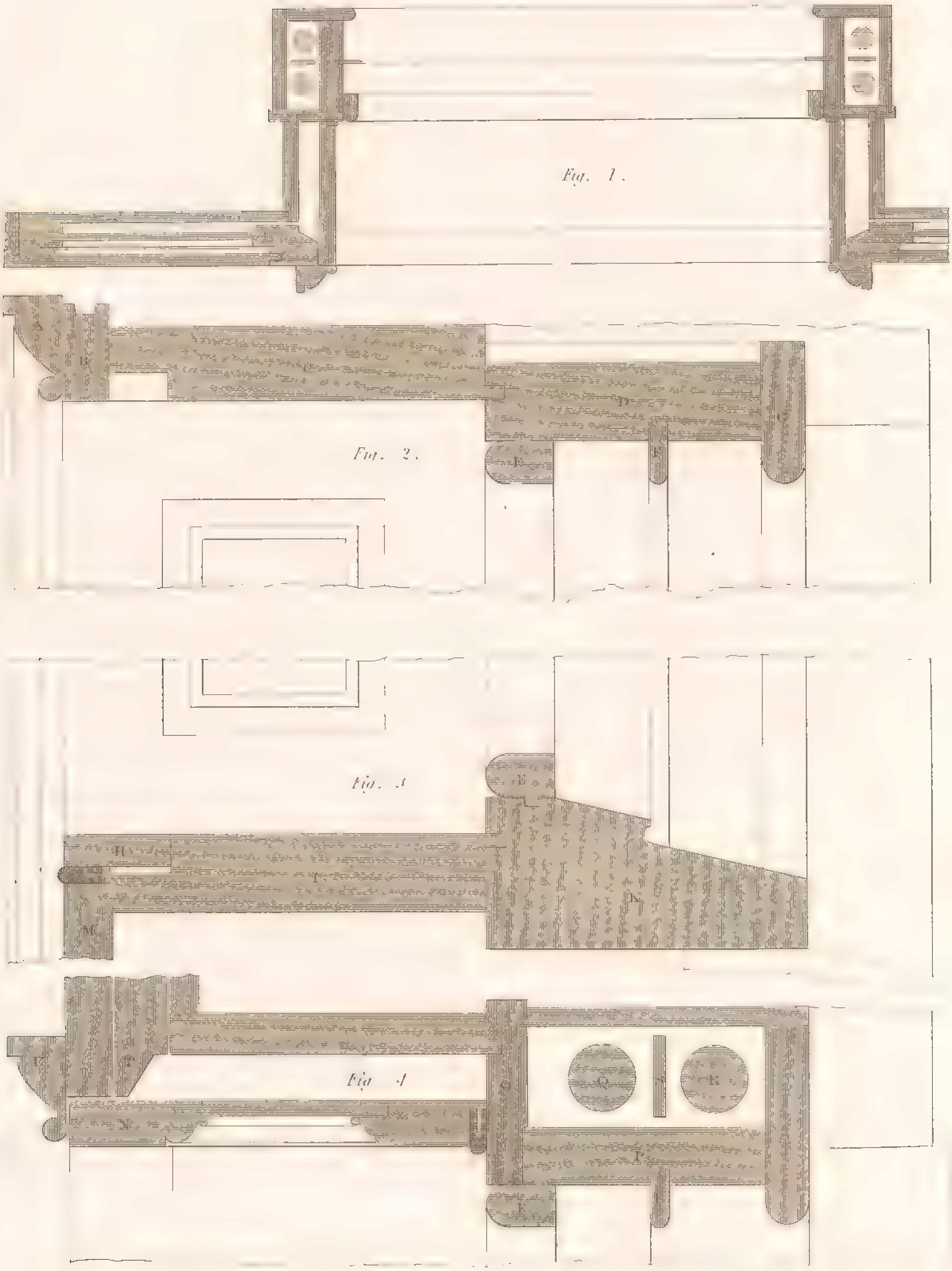
# DESIGNS FOR SHUTTING WINDOWS.



# Designs for Shutting Windows.

Fig. 1.

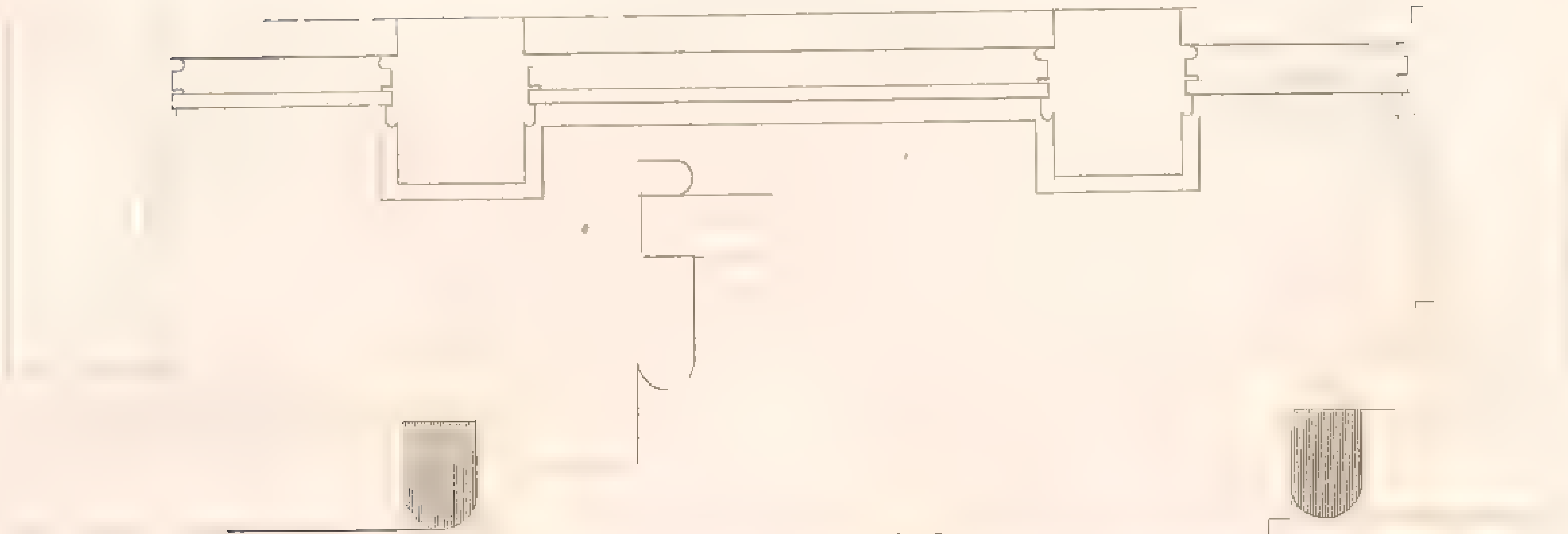


Fig. 2.

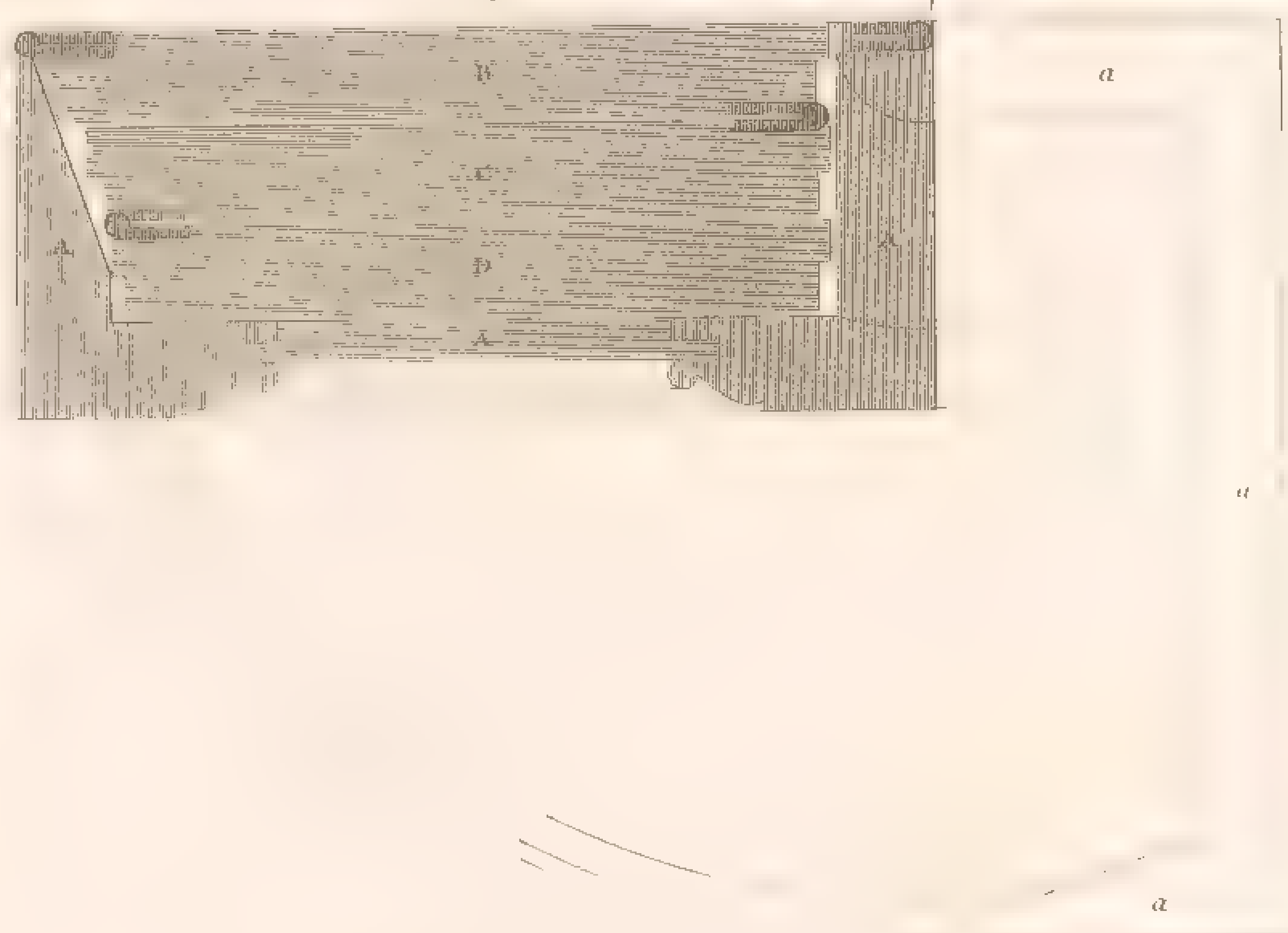


Fig. 4.

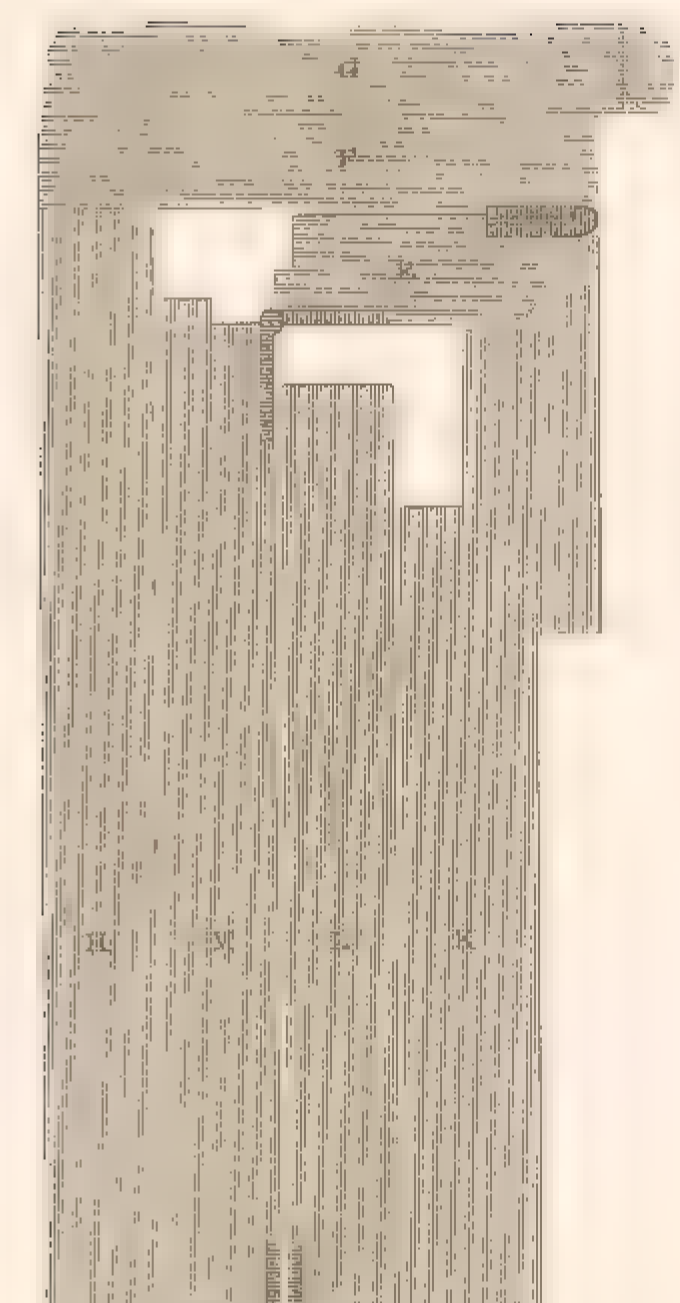
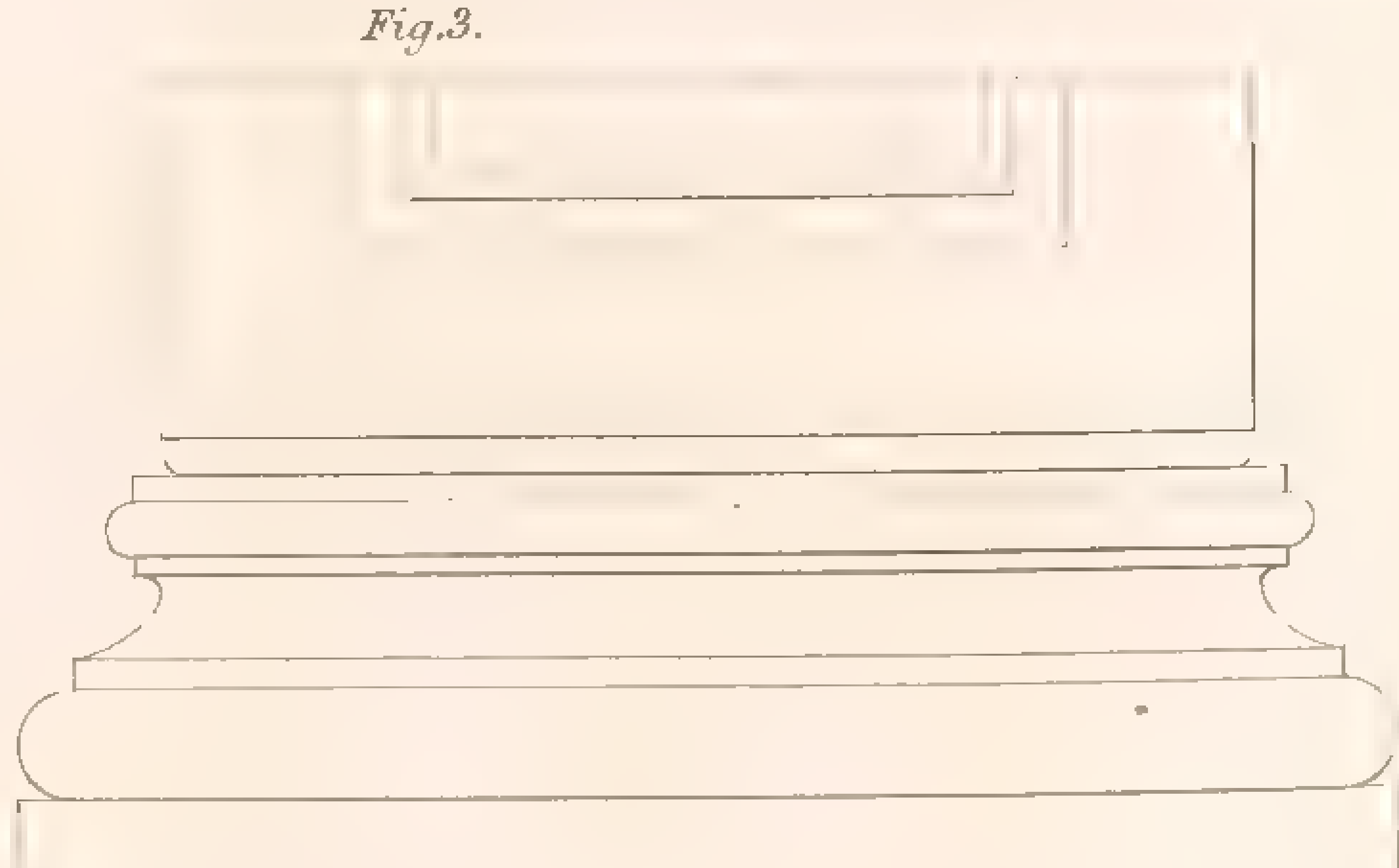


Fig. 3.



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H, The Inside Bead, forming one side of a groove for the lower sash to run in.

N, The Bottom Rail of the lower sash.

O, Sill of the sash-frame, being of a different section to the uprights.

P, Section of the back lining of the window.

*Figure* 3, Section of the sash-frame and shutters, where the wall is not sufficiently thick to admit of boxing-room for the shutters. Here ABECD is a casing of wood, in order to receive the shutters, which is made in two folds, F and G, the one, F, being parallel to the wall, and connected to the other, G, by a rule-joint, and G is connected to the sash-frame by butt-hinges.

*Figure* 1, (*pl.* XLVII,) is a Horizontal Section of a Sash-frame and Shutters.

Here, instead of the rule-joint, shown in the preceding plate, the shutters are made to draw or slide out of the wall, as shown, and the end is covered by a flap, as if it were a front shutter; and this flap is hung to the sash-frame in the usual manner, and may be so framed together.

*Figure* 2 is a vertical section through the head of the sash-frame.

D, Head of the sash-frame.

E, Inside Bead.

F, Parting Bead of the sash-frame.

C, The Soffit, tongued into the head of the sash-frame.

B, Ground, flush on the front side with the plaster.

A, Architrave Moulding.

*Figure* 3, Vertical Section through the window.

K, Sill of the sash-frame.

E, Inside Bead or Stop of the sash-frame, forming one side of a groove.

I, Window Sill.

H, A small flap hinged to the back, M, of the recess under the window.

*Figure* 4, a Horizontal Section through the sash-frame and shutters.

O, Inside Lining of the sash-frame.

P, Pulley-stile.

E, Inside Bead, forming a stop for the lower sash.

F, Parting Bead.

N, A Door hung to the sash-frame, in order to conceal the end.

T, Part of the section of the real shutter.

U, Architrave Moulding.

Q and R, Weights for balancing the sashes.

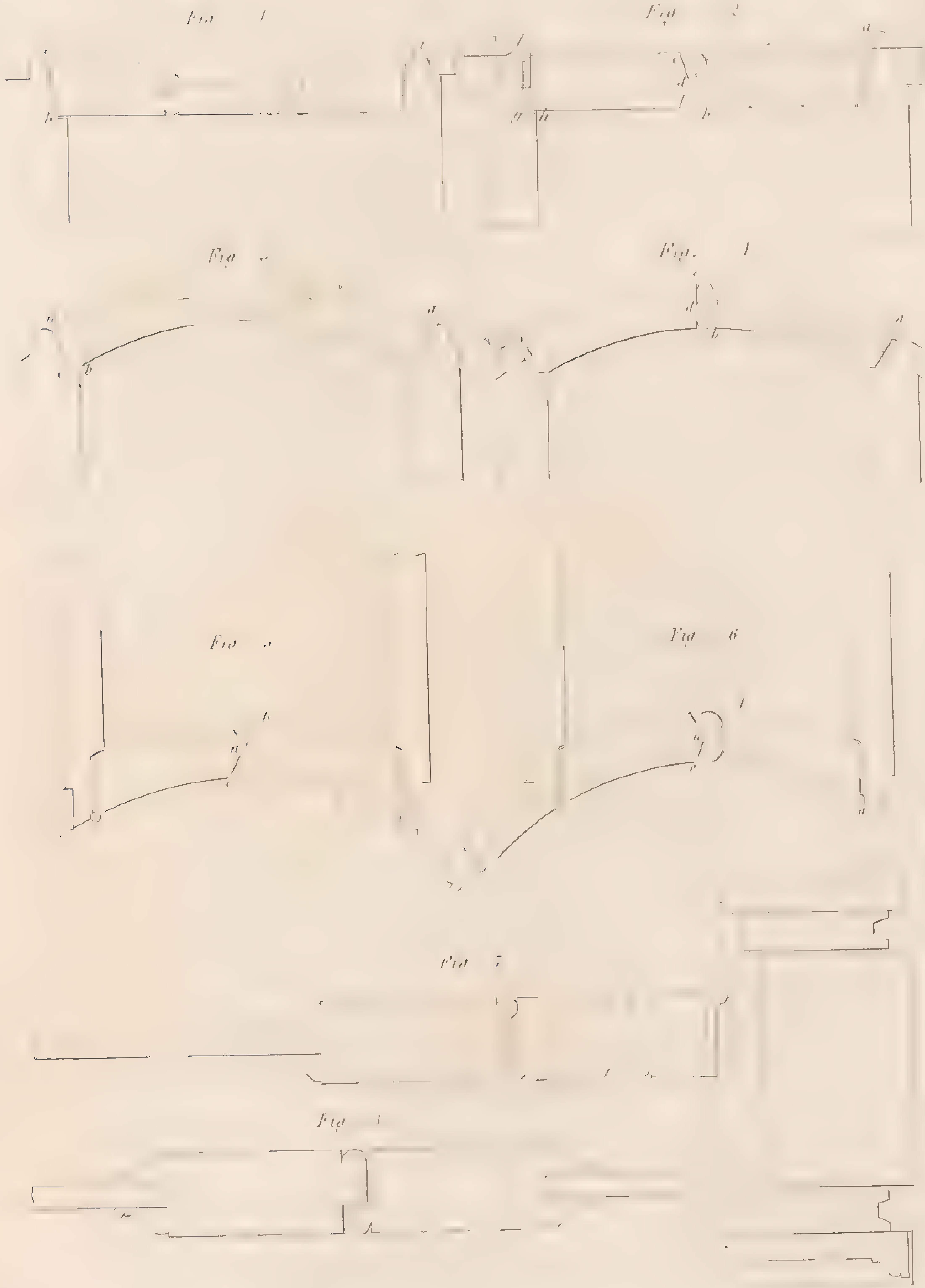
## ON THE FORMATION OF THE SHUTTING-JOINTS OF DOORS.

*Figure* 1, *pl.* XLIX, represents a *common door,* supposed to be hinged at *a.* The face of the door is in the line *ac,* and the breadth is terminated at *a* and *c.* On *ac,* as a diameter, describe a semi-circle, *abc,* cutting the other face of the door at *b.*

*Figure* 2, on the same plate, represents the section of *folding-doors* with jambs, upon a straight plan. Here we must suppose that one of the doors is shut, while the other opens. Let the half which is shut be *edcbhgf,* and let *aedcb* be the other half, which opens. Draw the line *dc,* parallel to the face of the door, bisecting the thickness, so that the middle of *cd* may be in the middle of the breadth of the door. Draw the line *ad,* and draw *de* perpendicular to *ad*; also draw the line *ac*; and on *ac,* as a diameter, describe the semi-circle *abc,* cutting the other line of the door at *b,* and join *cb*; then will *edcb* be the form of the joint.

The principle of opening is evident; since no length can be applied in a place shorter than itself. The most remote point of the thickness in the moving part must pass, in the act of opening, every other part of the half that is stationary. The principal, therefore, amounts to this: that, since in the opening every point in the edge of the moving door describes the circumference of a circle, every line drawn from the point *a* to the line *bc,* ought not to be less than the line *ab*; and, because the angle *abc* is a right angle, every line drawn from *a,* to meet the line *bc,* will be the hypothenuse

# FORMATION of the SHUTTING JOINTS of DOORS.

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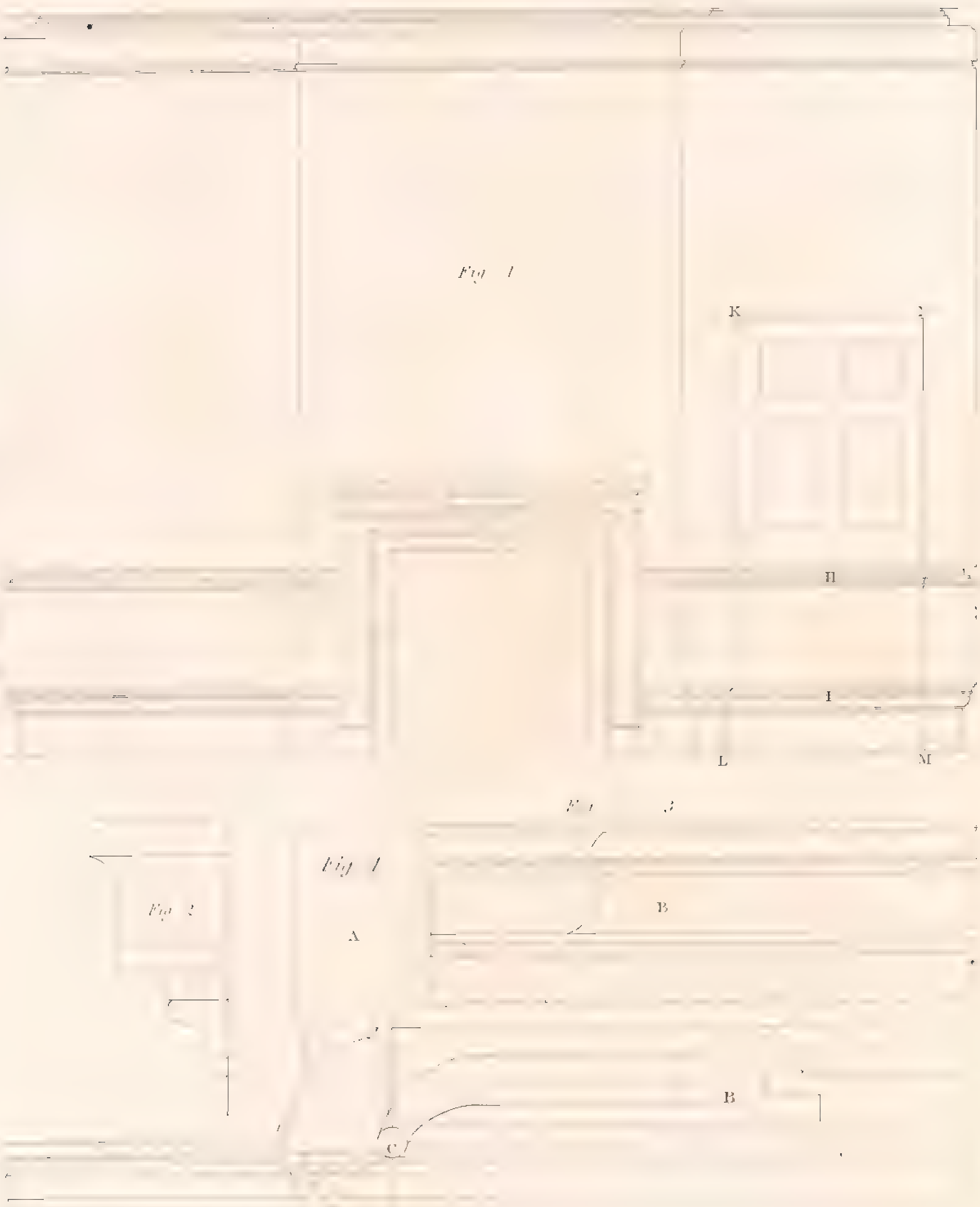
# JIBB DOORS.

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of a right-angled triangle, of which one of the legs is the line *ab*; therefore, *ab* is shorter than any line that can be drawn from the point *a* to the line *bc*; consequently, the point *b*, in the act of opening, would fall within the extremities of every line drawn from *a* to the line *bc*.

It may, also, be shown that, if any point be taken in *bc*, and a line be drawn from that point to the point *a*, the line thus drawn will be less than any other line drawn from *a* to any other point of the line *bc*, between the former point and the point *c*.

In the same manner, because *ade* is a right angle, the line *ad* is less than any other line that can be drawn from *a* to any point of the line *de*, between *d* and *e*; and every other line drawn from *a*, to any point between *d* and *e*, will be less than any other line drawn from *a* to any other point in *de*, between that point and the point *e*.

Having thus shown the reason of the method, the principle of *figures* 3, 4, 5, 6, will be evident on inspection; or, at least, by comparing it with the former part of this description.

*Figure* 7 is a section of the jambs of a pair of folding doors, with part of the section of the door: *fig.* 8, the section of the meeting-stiles of the doors.

## OF JIBB-DOORS. (*See Plate* L.)

A Jibb-door is one that has no corresponding door, and which is flush with the surface of the wall, being generally papered over, the same as the room; the design being to conceal the door as much as possible, in order to preserve the symmetry of the side of the room which it is in.

Let *fig.* 1 represent the side of a room, in which KLMN is a *jibb-door*, I the base of the room, and H the surbase, extending across the door.

Now, in order to make the jibb-door open freely, the mouldings must so be cut that no point of the moving part may come in contact with the jamb of the fixed part. This may be done by forming the end of the moving part,

and the end of the jamb or stationary part, in such a manner that all the horizontal sections may be circles described from the centre of the hinge. In short, by making the end of the base and surbase, and the edge of the jamb, the surface of a cylinder, of which the axis line of the hinges is the axis of the cylinder. This is shown by *fig.* 4, where A is part of the jamb; B represents a section of the door, upon which the iron containing the centre is fixed. C is the centre. The parallel lines in front represent the projections of the mouldings. Draw C*d* perpendicular to the front line, and make *de* equal to C*d*: from C, with the radius C*e*, describe the circular line *ef*, and where the points of *ec* cut the parallel lines will be the extremities of the radii of the other circles.

*Figure* 2 exhibits the section of the surbase, marked H, in *fig.* 1; and B, *fig.* 3, is the elevation of the base, shown at I, *fig.* 1.

## OF STAIRS AND STAIR-CASING.

### DEFINITIONS OF THE PARTS OF STAIRS.

1. By Stairs we mean an assemblage of steps, so formed and united, that, by walking on them, we ascend or descend from one height to another.

2. The surfaces on which we set our feet are called TREADS; and these, for the convenience of walking, are set at equal distances, and parallel to each other.

3. In order to give a solid appearance to the whole, every adjacent pair of treads are connected by a third and vertical piece, called a RISER. Each riser and tread, when fixed together, is called a STEP.

4. The wall which supports the ends of the steps is called the STAIR-CASE.

5. When the ends of the steps terminate upon a vertical prism or pillar, the prism or pillar is called a NEWEL.

6. If the ends of the steps be cut through in the surface of the *newel,* and the pillar or prism be supposed to be removed, the space left open by the removal of the solid is called the WELL-HOLE.

7. Stairs that have a well-hole, or hollow in the centre, are called GEOMETRICAL STAIRS.

8. The meeting of the sides which form the external angle of the steps is called the LINE OF NOSING; but sometimes the line of nosing is covered with a moulding, and then this moulding is called the *nosing.*

9. When the steps are of equal breadth; that is, when the distance from the line of nosing to the riser is every where equal, the steps are denominated FLYERS.

10. When the treads of the steps diminish in breadth toward the well-hole, the steps are called WINDERS.

As the ends of the steps generally terminate upon a surface which is perpendicular both to the risers and treads, the surface on which they thus terminate is generally that of a cylinder.

11. A number of contiguous flyers are called a FLIGHT.

12. When the tread of a step is so broad as to be equal to two or more of the other steps, and situated between floors, it is called a RESTING-PLACE.

13. If the tread of the resting-place form a right angle, that is, if the two risers be perpendicular to each other, the resting-place is called a QUARTER-SPACE or QUARTER-PACE.

14. When the breadth of the tread of a step is contained between the same vertical plane, or makes two right angles round the axis of the well-hole, the tread is called a HALF-SPACE or HALF-PACE.

15. Half-spaces and quarter-spaces are generally made on floors; and, in this case, are called *landing-places.*

## PROPORTIONS, &c.

The breadth of the steps of common stairs is from nine to twelve inches. In the best stair-cases of noblemen's houses and public edifices, the breadth ought never to be less than twelve, nor more than fifteen, inches.

A step of greater breadth requires less height than that of a less breadth. The general rule may therefore be as follows:

Multiply the breadth and height of a given step together, and divide the product by the breadth of the required step, and the quotient will be the answer: or, by reciprocal proportion, as the given breadth belonging to the height required is to the breadth of the given step, so is the height of the given step to the height of the required step.

For *example*, taking as a standard a step of 12 inches in breadth, and $5\frac{1}{2}$ inches in height, we may easily find the height of another of a given breadth, which we shall suppose to be 10 inches. The operation is $10 : 5\frac{1}{2} :: 12 : \frac{12 \times 5\frac{1}{2}}{10} = 6\frac{3}{5}$ inches.

Again, suppose we would find what ought to be the height of a step of which the breadth is nine inches; the operation will be thus:

$$\begin{array}{r} 9 : 12 :: 5\frac{1}{2} \\ 5\frac{1}{2} \\ \hline 60 \\ 6 \\ \hline 9)\,66 \\ \hline 7\frac{1}{3} \text{ inches,} \end{array}$$

which agrees with what would be allowed in common practice.

Before we lay out the stairs in a building, we must consider the height of the story, and determine upon the height of the steps; which, being done, we must throw the height of the story into inches, and divide the number of inches in the height of the story by the height of the step. Thus, for example, suppose the height of the story to be ten feet four inches, and the height of the step to be seven inches, how many steps will be required in order to ascend to the given height?

Here $(10\,ft.\ 4\,in.) \times 12 = 124$ inches. Now $124 \div 7 = 17\frac{5}{7}$, which is the number of steps required; but, as we must not have a fractional part, the stairs must consist of either seventeen or eighteen steps: if the plan admits of sufficient room, eighteen steps would be preferable to seventeen. But, if there are no winders in the stairs, an even number of steps will be more con-

venient than an odd number: therefore, if we cannot have eighteen, we must have sixteen: now, $124 \div 16 = 7\frac{3}{4}$ inches; which may answer very well: but, if we are still confined for room on the plan, we must throw the semi-circumference round the newel into winders.

The breadth of stair-cases may be from five to twenty feet, according to the destination of the building; but if the steps be less than two feet four inches in length, they become inconvenient for the passing of furniture, as is generally the case in small houses.

When the height of the story is very considerable, resting-places become necessary. In very high stories, that admit of sufficient head-room, and where the plan or area for the stairs is confined, the stairs may make two revolutions in the height of the story; that is, the ascendant or descendant may go twice round the newel or well-hole; and this becomes necessary, otherwise the steps would be enormously high, or extravagant floor-room must be allowed for the stairs.

As grand and principal stair-cases require broad and low steps, they therefore require to be numerous, and admit of only one revolution in the height of the story; the plan being always proportioned to the height of the building.

It may not be amiss to give an example here for a principal building, in order to show the number of steps both in the grand and in the common stair-case.

For this purpose, suppose the story of a house to be sixteen feet high from floor to floor, the height of the steps of the servants' stair-case to be seven inches, and that of the grand stair-case to be six inches.

Now the height of the story reduced to inches is 192, and first dividing by 7, thus—

$$7\overline{)192}$$
$$27\tfrac{3}{4}$$

then, dividing by 6, thus—

$$6\overline{)192}$$
$$32$$

So that the servants' stair requires very nearly twenty-eight steps, and the grand stair-case thirty-two: but the space or area required to execute the common would not be much less than that required to execute the grand stair-case; the common stairs must therefore have two revolutions in the height. This being allowed, will reduce the area to half of what it otherwise would have required.

We must, however, observe that, when the height of the story is less than fourteen feet, the stairs will not admit of two revolutions.

In planning a large edifice, particular attention must be paid to the situation of the stairs, so as to give the most convenient and easy access to the several rooms.

With regard to the lighting of a grand stair-case, a lantern-light is the most appropriate. By introducing this, more elegance is acquired, and the light admitted is more powerful; but, indeed, where one side of the stair-case is not a portion of the exterior wall, a lantern or skylight is the only way in which the light can be admitted.

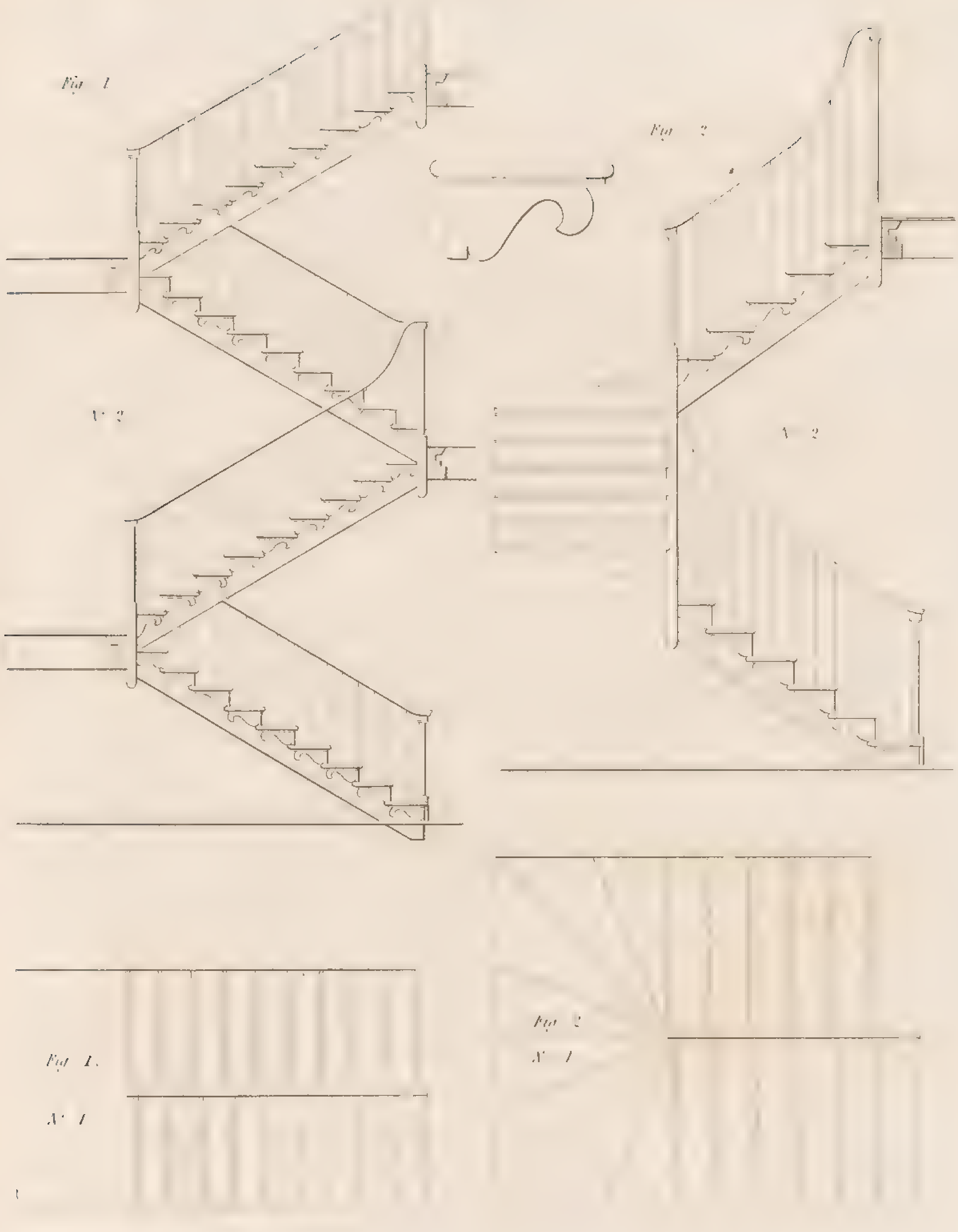
In stairs constructed of stone, the steps are made of single blocks; quarter-spaces and half-spaces are, however, made in two or more pieces, and joggled together: but, when the material is wood, the risers and treads must be made of boards, which are fastened together with glue, brackets, and screws; and these, though done with the utmost care, can never be made so firm as not to yield to the passenger.

To prevent stairs from becoming ricketty, in length of time, the steps must have an additional support under them; and that the appearance may be both light and pleasant, the whole must be confined to as small a space as possible. This additional wood-work, which is necessary to the firmness and durability of the construction, is called the CARRIAGE OF THE STAIRS.

The *carriage of a stair* consists of several pieces joined together.

A flight of steps is generally supported by two pieces of timber, placed under the steps, and parallel to the wall, being fastened at one or both ends to pieces perpendicular thereto.

# STAIRS.

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The pieces of timber which are thus placed under the steps are called ROUGH STRINGS.

DOG-LEGGED STAIRS are those which have no well-hole, and consist of two flights, with or without winders. The hand-rail, on both sides, is framed into vertical posts, in the same vertical plane, as well as a board which supports the ends of the steps. The boards are called STRING BOARDS, and the posts are called NEWELS. The newels not only connect the strings, but they afford the principal support to the rail; and thus it may be affirmed that the newels, posts, and hand-rail, are all in one plane.

OPEN-NEWELLED STAIRS are those which have a rectangular well-hole, and are divided into two or three flights. (See *fig.* 2, *pl.* LI.)

BRACKETED STAIRS are those where the string-board is notched, so as to permit the risers and treads to lie upon the notches, and pass over beyond the thickness of the string-boards: the ends of the steps are concealed by means of ornamental pieces called BRACKETS.

Geometrical stairs are generally bracketed; but, in dog-legged and open-newelled stairs, only those of the best kind are bracketed.

A PITCHING-PIECE is a piece of timber wedged into the wall, in a direction perpendicular to the surface of that wall, for supporting the rough strings at the top of the lower flight, when there is no trimmer, or where the trimmer is too distant to be used for the support of the rough strings.

BEARERS are pieces of timber fixed into, and perpendicular to, the surface of the wall, for supporting winders when they are introduced; the other end of the bearers is fastened to the string-board.

A NOTCH-BOARD is a board into which the ends of the steps are let: it is fastened to the wall, or one of the walls, of the stair-case.

CURTAIL-STEP is the lowermost step of stairs, and has one of its ends, next to the well-hole, formed into an ornament representing a spiral line.

These are the principal parts which belong to a stair or stairs; other parts connected with it belong to the HAND-RAIL, and will be all defined in the following article.

## CONSTRUCTION OF DOG-LEGGED STAIRS.

Having taken the dimensions of the stair, and the height of the story, lay down a plan and section upon the floor, to the full size, representing all the newels, string-boards, and steps; by this method the lengths and distances of the parts will be ascertained, as also the angles which they make with each other. The quantity of head-room, the situation of apertures and passages, will also be ascertained, and will determine whether quarter-spaces, half-spaces, or winders, are to be introduced.

But, in order to give the most variety in the construction, we shall suppose the stairs to have two quarters of winders; the whole being represented as framed together, the string-board will show the situation of the pitching-pieces, which must be put up next in order, by wedging the one end firmly into the wall, and fixing the other end into the string-board; which, being done, put up the rough-strings, and put up the carriage part of the flyers. In dog-legged stair-cases the steps are seldom glued up, except in cases where the nosings return; we shall therefore suppose them in separate pieces, and proceed to put up the steps.

Place the first riser in its intended situation, fixing it down close to the floor, the top at its proper level and height, and the face in its true position. Nail it down with flat-headed nails, driving them obliquely through the bottom part of the riser into the floor, and then nailing the end to the string-board.

Place the first tread over the riser, observing to give the nosing its proper projecture over the face of the riser; and, to make it lie more solid upon the string, notch out the wood at the farther bottom angle of the riser, where it is to come in contact with the rough-strings, so as to fit it closely down to a level on the upper side, while the under edge beds firmly on the rough-strings at the back edge, and to the riser at the front edge: nail down the tread to the rough-strings, by driving the nails from the place on which the next riser stands, through that edge of the riser, into the rough-strings, and then nailing the end to the string-board.

Begin again with the second riser; which, being brought to its breadth, and fitted close to the top of the tread, so that the back edge of the tread below it may entirely lap over the back of the riser, while the front side is in its real position. Then nail the tread to the riser from the under side, taking care that the nails do not go through the face, which would spoil the beauty of the work.

Proceed with riser and tread, alternately, until the whole of the flyers are set and fixed.

Having finished the first flight of steps, fix the top of the first bearer for the winding-tread on a level with the last parallel riser, so that the farther edge of this bearer may stand about an inch forward from the back of the next succeeding riser, for the purpose of nailing the treads to the risers upwards, as was done with the treads and risers of the flyers. The end of this bearer being fitted against the back of the riser, and having nailed or screwed it fast thereto, fix then a cross-bearer, by letting it half its thickness into the adjacent sides of the top of the riser, and into the top of the long bearer, so as not to cut through the horizontal breadth, nor through the thickness of the riser, which will weaken the long bearer, and injure the appearance of the work: then fix the riser to the newel.

Try the first winding step-board to its place; then, having fitted it to its bearings, and to the newel, with a re-entrant angle, or bird's mouth, fix it fast. Proceed with all the succeeding risers and step-boards until the winders are complete.

Having finished the winders, proceed with the retrogressive or upper flight, exactly in the same manner as has been done with the lower flight.

The workman must then proceed to strengthen the work in the following manner: fix rough brackets into the internal angles of the risers and step-boards, so that their edges may join upon the sides of the rough-strings, to which they are fixed by nails, and thus the work is completed.

N.B. In the best dog-legged stairs the nosings are returned, and sometimes the risers mitred to the brackets, and sometimes mitred with quaker-strings. In this case, a hollow must be mitred round the internal angle of the under

side of the tread and face of the riser. Sometimes the string is framed into a newel, and notched to receive the ends of the steps ; and, at the other end, a corresponding notch-board, and the whole of the flyers are put up in the same manner as a step-ladder.

By paying proper attention to what has here been said, a workman of good understanding will be able to execute such stairs, and put them up in the most sufficient manner, although he might never have seen one made or put up before.

## BRACKETED STAIRS.

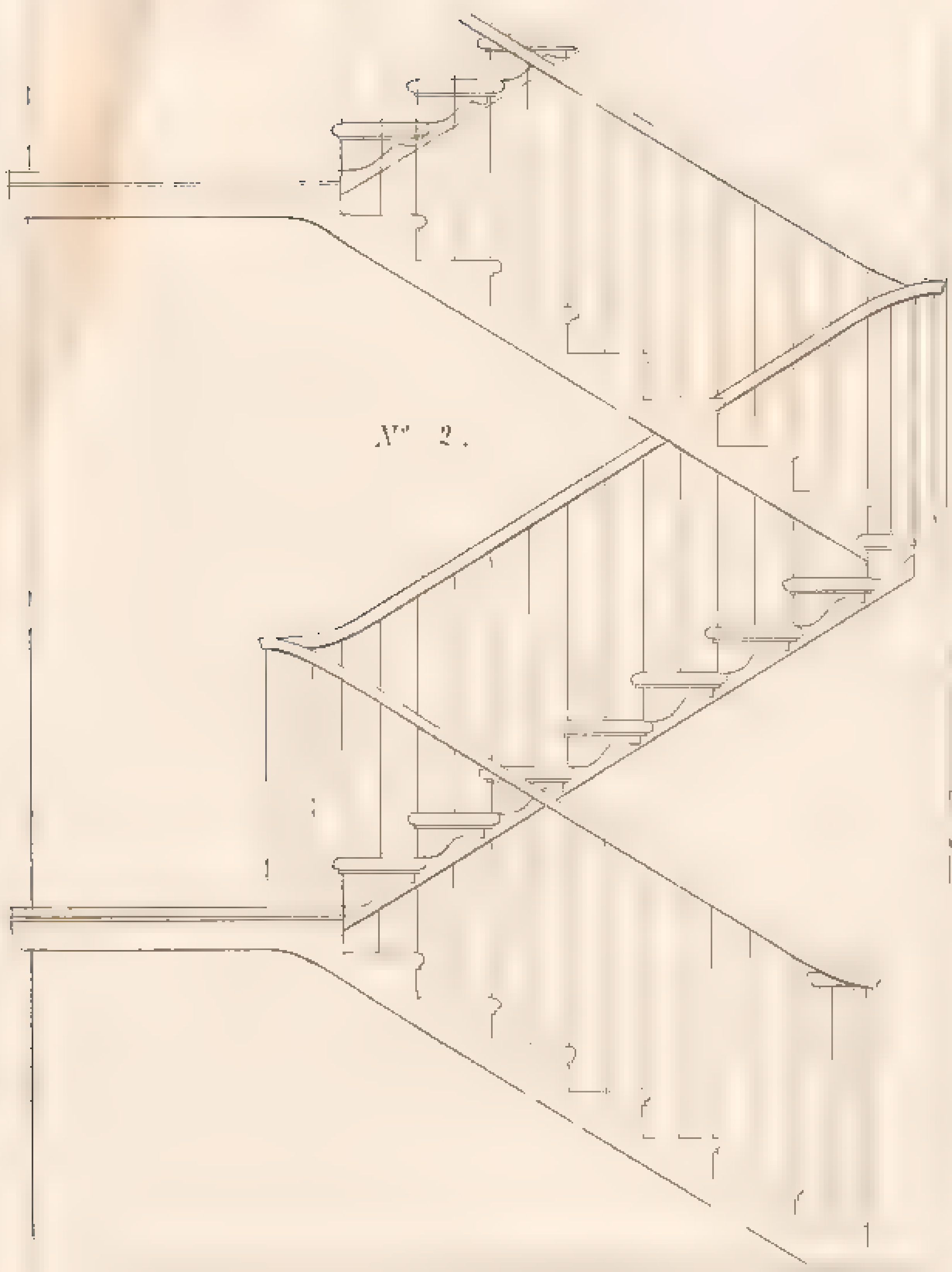
Here the same method of laying down the plan and section must be observed as in dog-legged stairs. The balusters must be neatly dovetailed into the ends of the steps, two dovetails being put in each, in such a manner that one of the balusters may have one of its faces in the same plane with the riser, and the other face in the same plane with the face of the bracket.

## GEOMETRICAL STAIRS.

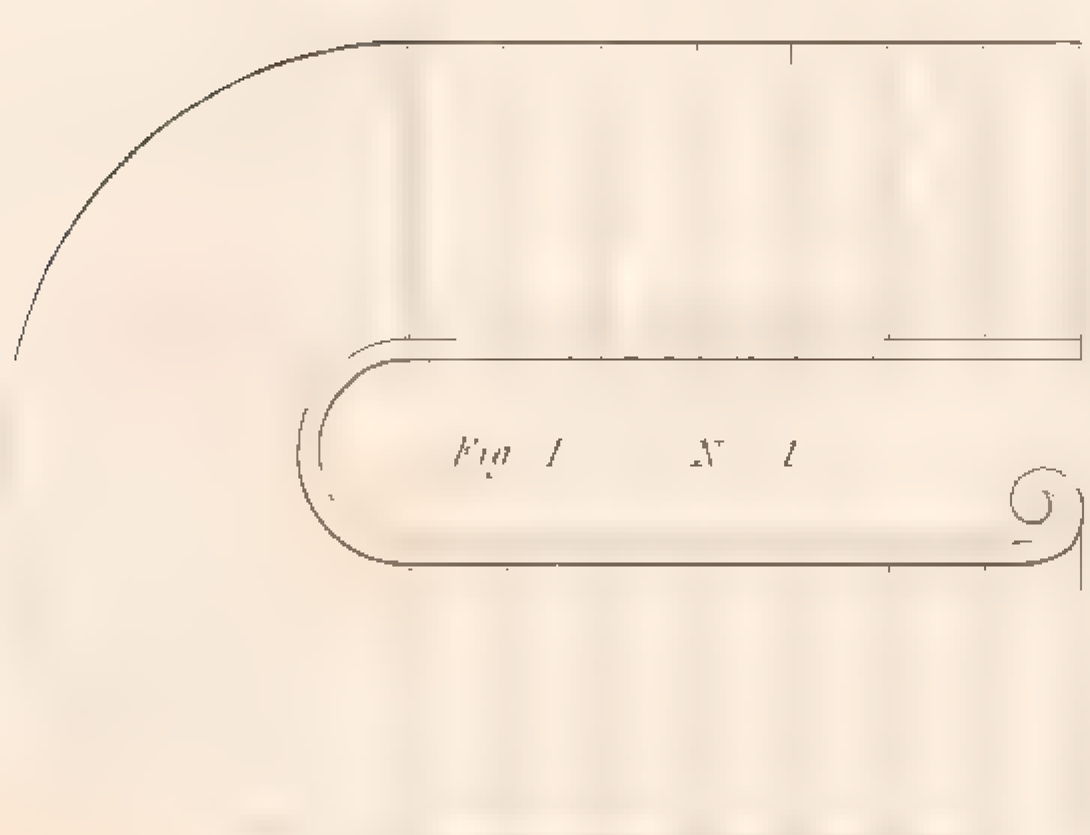
The steps of Geometrical Stairs ought to be neatly finished, so that they may present a handsome appearance. The risers and step-boards ought not to be less than one inch and a quarter thick. The risers and step-boards ought to be well glued and secured together, with blockings glued in the internal angles. When the steps are set, the risers and step-boards must be fixed together by screws, passing from the under side of each horizontal part into the riser. The brackets must be mitred to the risers; and the nosings, with a cavetto underneath, should be returned upon the brackets, and stopped upon the string-board. The under side may be finished with lath and plaster. In many old buildings, where the principal stairs were constructed of wood, it was customary to panel the soffit; but this is now very seldom done, except in pulpit-work, as the difficulty and time required to execute the work occasions very great expenses to the proprietor.

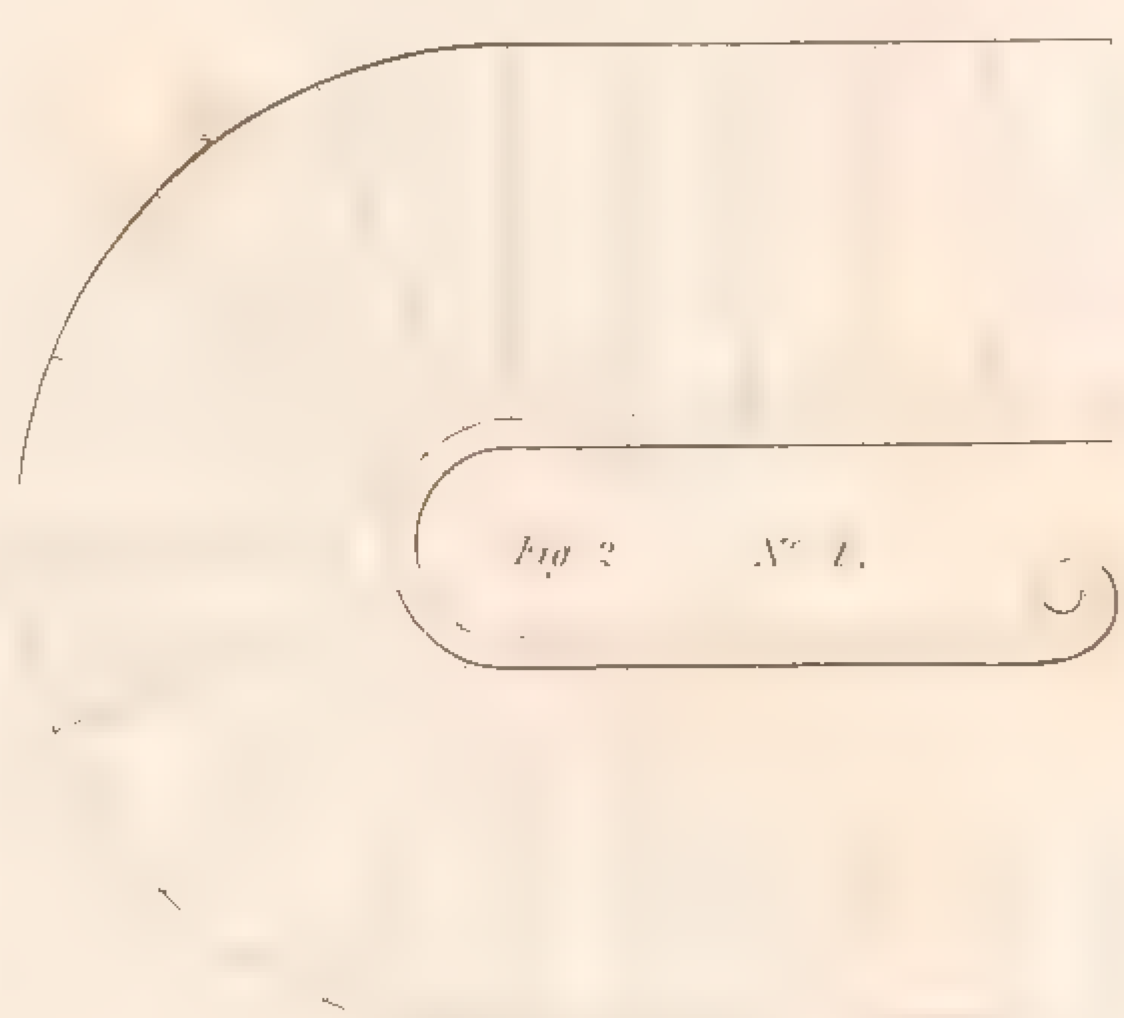
# STAIRS.

Fig. 1.








Engraved by W. Symns

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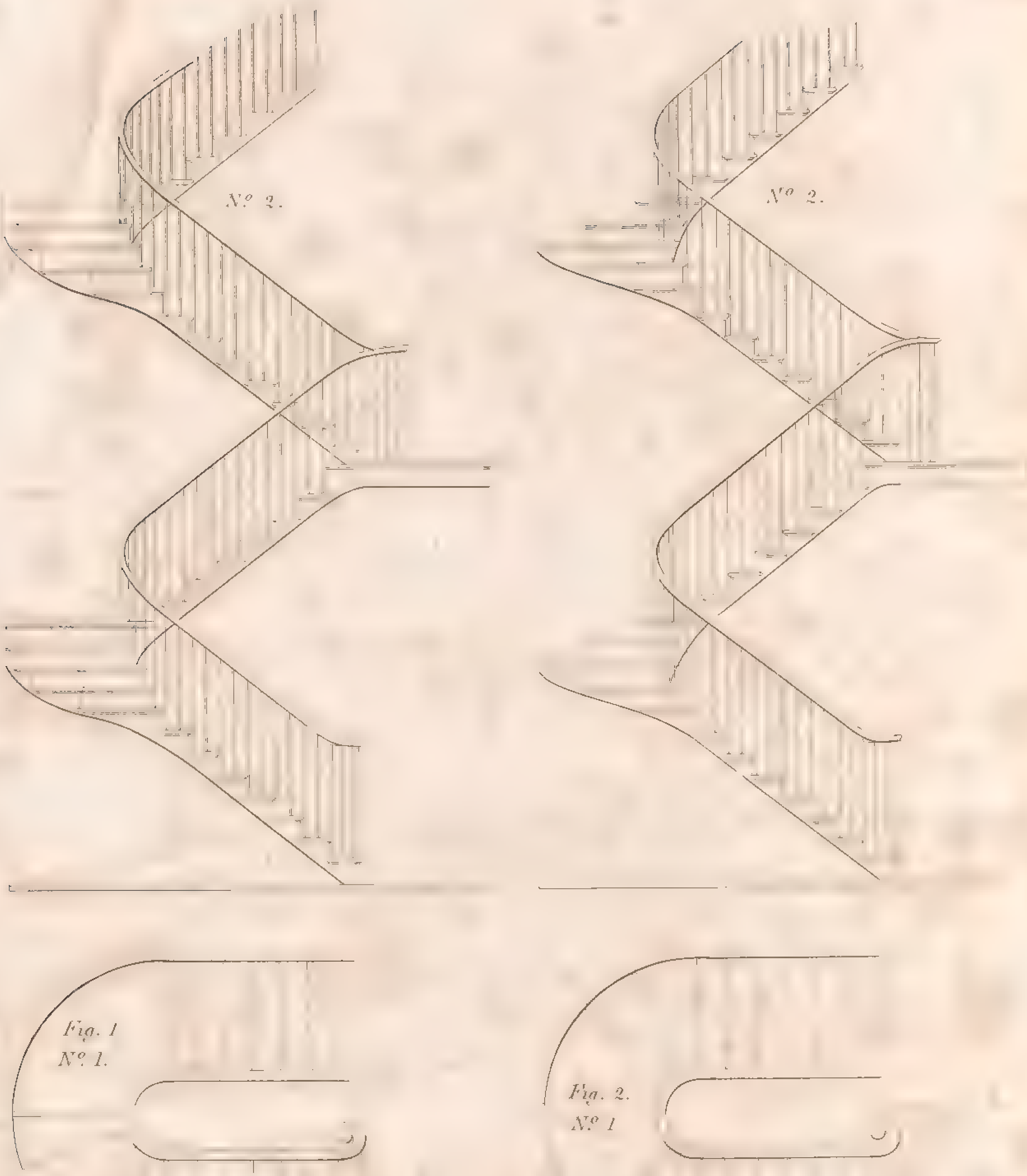
# STAIRS.

*Fig. 1* *Fig. 2.*




Drawn by P. Nicholson

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# STAIRS.

Fig. 3.

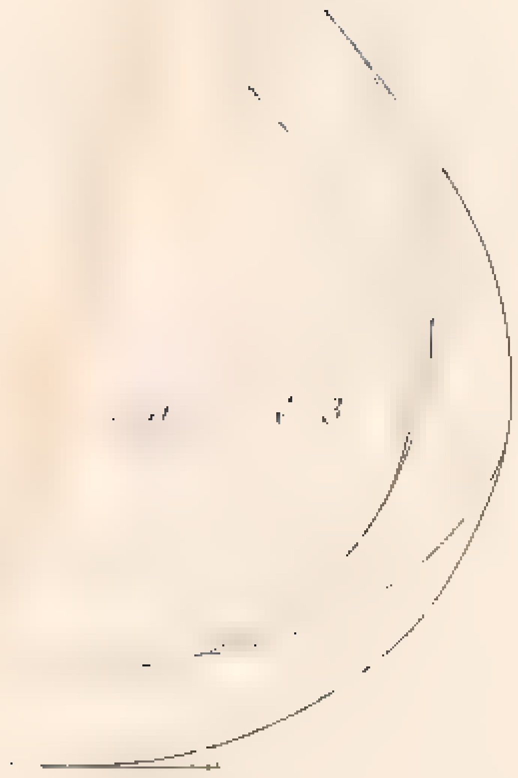
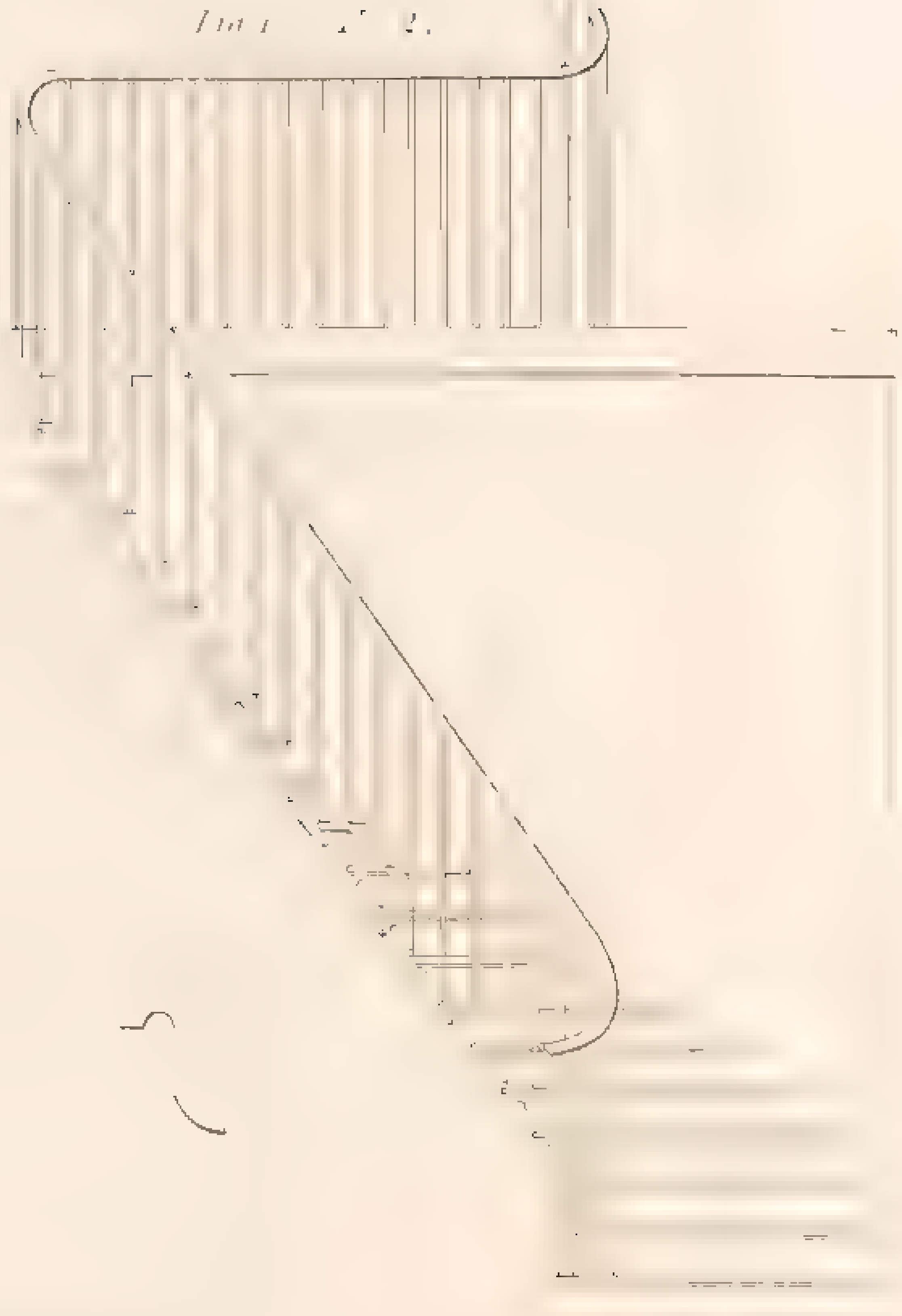


Fig. 2.



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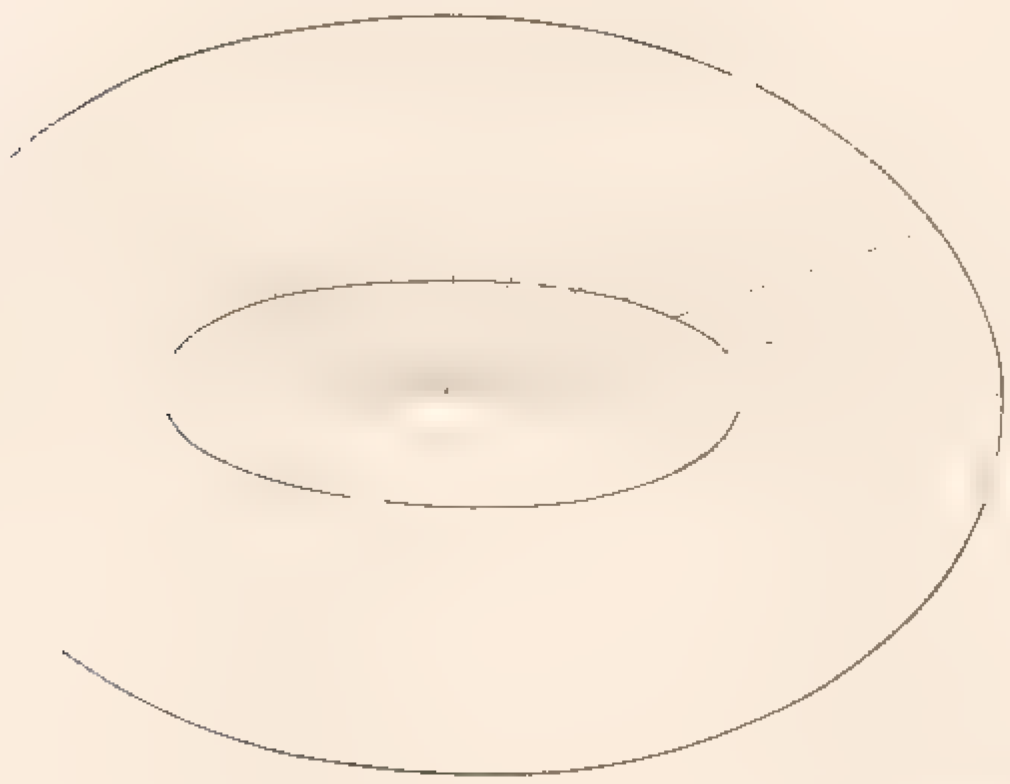
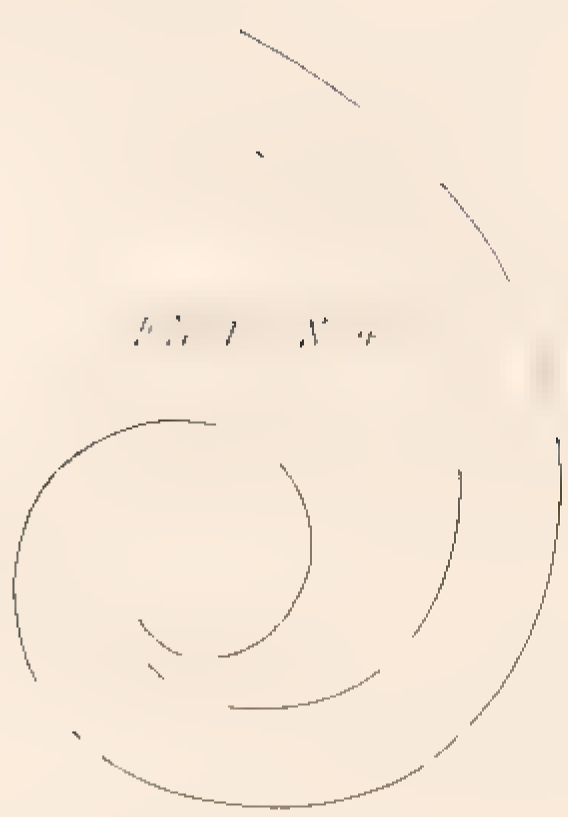
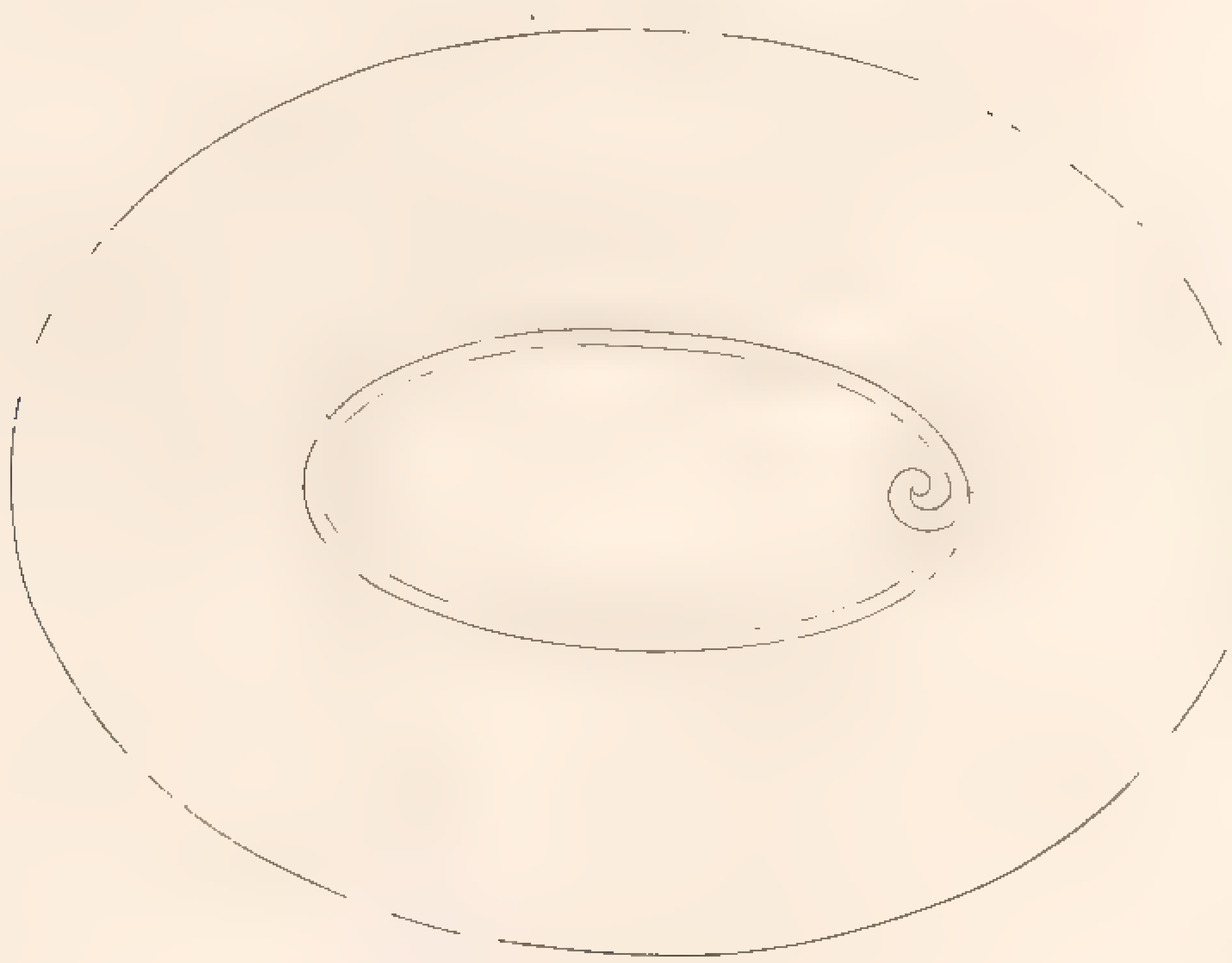


Fig. 4.





Drawn by P. Nicholson.

Engraved by W. Evans.

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Geometrical Stairs are sometimes finished without brackets, the risers being mitred to the string-boards, instead of brackets; and this mode is mostly practised in ordinary works.

As the parts of a geometrical stair form the subject of the following article upon hand-railing, the other connecting parts will be specified in their proper place.

Geometrical Stairs are mostly on a semi-circular plan, with a flight below, and another above; sometimes the plan is formed by four lines, at right angles with each other, and connected by quadrants of circles.

*Figure* 1, *pl.* LI, represents Dog-legged Stairs with flyers only; that is, which consist of steps of equal breadth. No. 1 is the Plan, showing the length and tread, or breadth, of the steps; or that which shows their exact area. No. 2, the Elevation, shows the sections or ends of the steps.

*Figure* 2 represents Dog-legged Stairs with winders, connecting the two straight flights. No. 1 is the Plan, showing the areas of the heads of the steps, as before. No. 2, the Elevation, shows the ends of the steps in the two flights, and the risers in both quarters of the winders.

*Figure* 1, *pl.* LII, is a Geometrical Stair-case, without winders. No. 1 is the Plan, and No. 2, the Elevation of the same.

*Figure* 2, a Geometrical Stair-case, with winders in both quarters. No. 1 is the Plan, showing the areas of the steps; and No. 2 is the Elevation, showing both the height and breadth of the steps, as, also, the proper turnings of the rail.

*Figure* 1, *pl.* LIII, represents Geometrical Stairs, with winders in one quarter. No. 1 is the plan; and No. 2, the Elevation, shows the turnings of the rail, agreeably to the plan.

*Figure* 2 is a Plan and Elevation of a Geometrical Stair-case, with winders adjoining each flight, and a space between the winders. No. 1 is the Plan; and No. 2, the Elevation of the same.

*Figure* 1, *pl.* LIV, is a representation of an Elliptic Stair-case. No. 1, the Plan; No. 2, the Elevation.

No. 3 is the Elevation of the Twist and Scroll, which terminates the rail.

No. 4, Plan of the Scroll, agreeing in size with No. 3.

In No. 1 the steps of the stair are equally divided round the wall-line, and equally divided round the inside of the rail. This mode of division lessens the acuteness which would otherwise be occasioned at the angles when the lines are drawn to the centre of the plan. The effect of drawing the lines which represent the risers of the steps is exhibited in *fig.* 2, where the half of the outside ellipse is divided equally, and the lines which represent the risers are drawn to the centre of the plan.

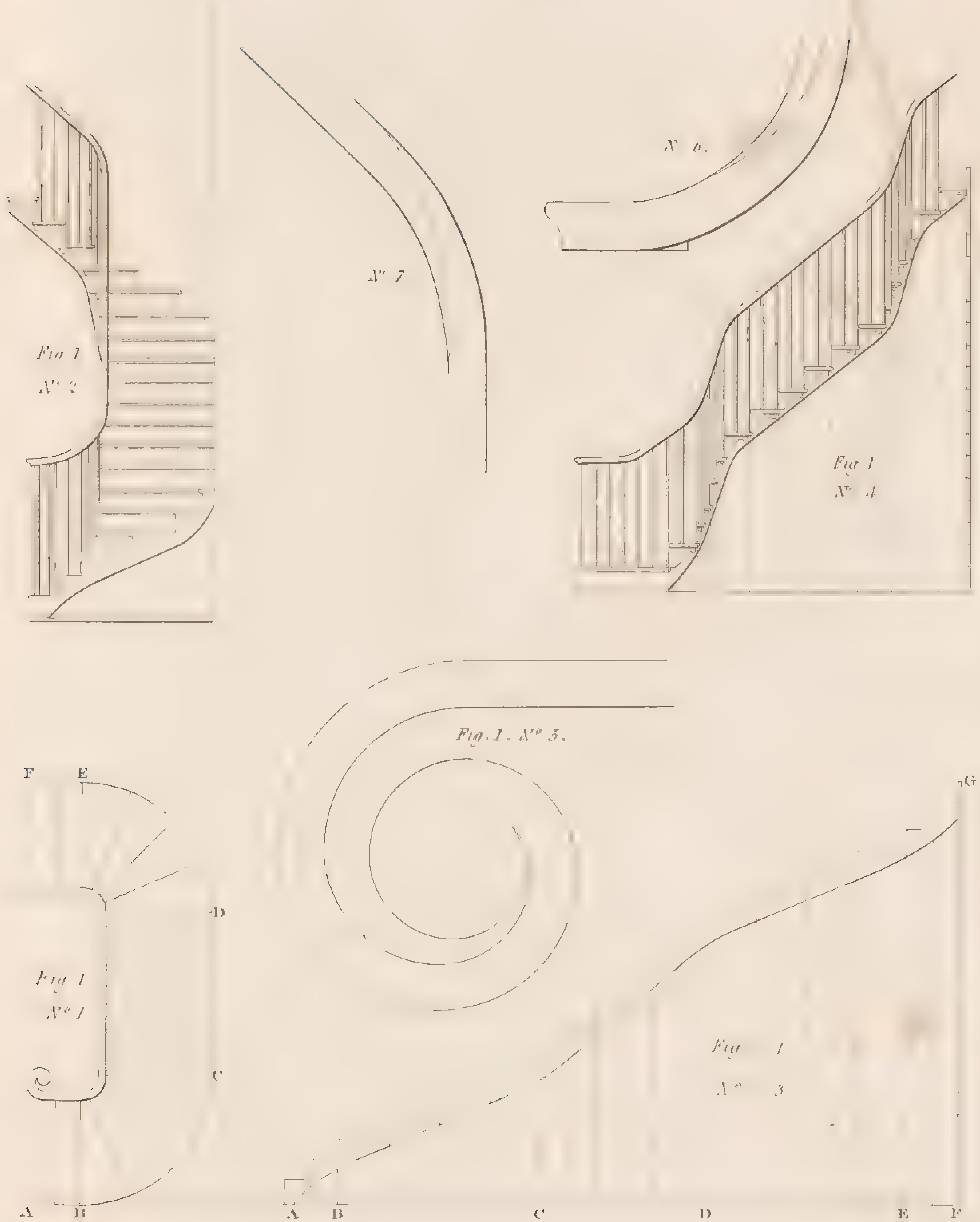
When the steps are equally divided at the well-hole, the development of the external as well as the internal points of the steps will form a straight line. But, if they are divided as in *fig.* 2, as the breadth of the steps increases towards the extremities of the major-axis, the points of the external and internal angles of the development will be in a curve of contrary flexure.

There are several ways in which we can conceive the steps to be divided: one of these is to suppose them perpendicular to one of the curves; for they cannot be perpendicular to both: but this method renders the steps very unpleasant to the eye, as it makes them so very broad next to the wall, and so very narrow at the rail, that it has a very unpleasant effect in comparing the whole together. Another method is to proportion their breadths to the curvature of the wall and rail-lines: but this must be done only with regard to the inner curve, as the steps ought to be of an equal breadth at the middle.

*Figure* 1, *pl.* LV, is the representation of Geometrical Stairs, consisting of a series of flyers between two quarters of winders. No. 1 is the Plan; No. 2, the Elevation.

No. 3 is the development of the steps next to the well-hole. This is found by extending the base-line upon a straight line; as AB, No. 1, upon AB, No. 3; the arc BC, No. 1, upon BC, No. 3; the straight line CD, No. 1, upon CD, No. 3; DE, No. 1, upon DE, No. 3; and EF, No. 1, upon EF, No. 3: so that ABCDEF, No. 3, will be the line ABCDEF, No. 1, extended in a straight line. Through all the points of division draw lines perpendicular to AF.

# STAIRS.

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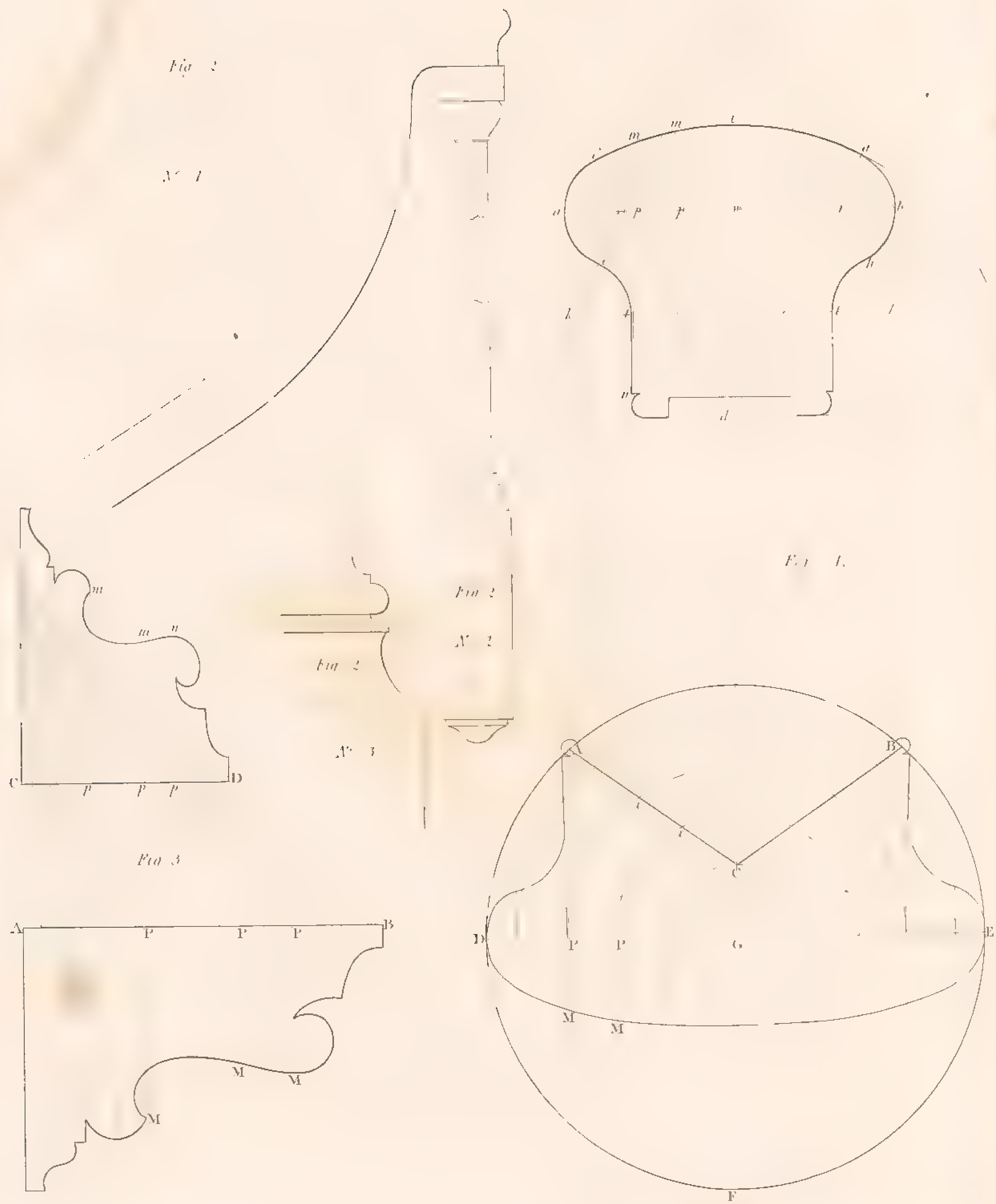
# STAIRS.

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Set the heights of the steps upon the perpendicular line FG, and through the points of division draw lines parallel to AF; then the horizontal parts meeting their corresponding heights will form the steps.

*Figure* 1, No. 4, is a development of the steps and rail next to the well-hole, found exactly in the same manner as No. 3.

These developments are of the greatest utility to the workman, as they enable him to judge of the proper form of his rail, so as to make it in the most agreeable and easy manner. Wherever there is an angle, that angle must be reduced, by taking it off in the form of a curve, which is more pleasant to the eye than a sudden change in the direction of the line. The taking away of an angle, either of the rail or string-board, is called by workmen the *easings* of the rail, or of the string.

*Figure* 1, No. 5, is the Plan of the Scroll to about one-sixth part of the real size.

*Figure* 1, No. 6, the side Elevation of the Scroll.

*Figure* 1, No. 7, the wreath or twisted part, at the turn of the rail above, between the winders and the upper flight of steps.

## THE METHOD OF DESCRIBING THE SECTION OF THE HAND-RAIL AND MITRE-CAP FOR DOG-LEGGED STAIRS; (*fig.* 1, *pl.* LVI.)

Draw the straight line *ab*, and make it equal in length to the breadth of the rail. Bisect *ab* by the perpendicular *i*G, cutting *ab* at *w*; make *mi* equal to two-sevenths of the depth of the rail, and *wd* equal to five-sevenths of the said depth. Draw *dn* perpendicular to *di*. Produce *di* to *c*, and make *wc* equal to *wd*. From *d*, with the radius *di*, describe the arc *ign*. Join *nb*, and produce *nb* to *g*. Draw *gd*, cutting *ab* in *r*. Make *ws* equal to *wr*. Join *ds*, and produce *ds* to *f*. Join *cr*, *cs*, and produce *cr* to *h* and *l*, and *cs* to *e* and *k*. From *d*, with the radius *di*, describe the arc *fg*. From *r*, with the radius *rg*, describe the arc *gbh*; and from *s*, with the radius *sf*, describe the arc *fae*. Make *hl* equal to *hr*, *ek* equal to *es*, and join *kl*. From *k*, with the radius *ke*, describe the arc *et*; and from *l*, with the radius

*lh*, describe the arc *ht*; and draw *tu* and *tv*, parallel to *id*; which completes the geometrical part of the section.

From any centre, as G, in the line ED, and *id* produced, with a radius equal to that of the mitre-cap, describe the circle ABEFD. Draw *a*A, *b*B, parallel to *i*C. Join AC and BC, for the angle of the mitre; C being taken at pleasure. Draw DE the diameter of the mitre-cap. In the curve of the section of the rail, take any number of points, *m*, *m*. Draw the lines *px* parallel to *i*G, cutting AC in the points C, *x*. From G, with the radii G*x*, G*x*, &c., describe arcs *x*P, *x*P, &c. Draw the ordinates PM, PM, &c., perpendicular to DE. Then, when as many of the points are found as is necessary, draw a curve through them, and this curve will be the contour of the section of the mitre-cap.

*Figure* 2 exhibits the method of drawing the Swan-neck of a dog-legged stair. No. 1, the Swan-neck and part of the capital; No. 2, the base; No. 3, the base, more at large.

*Figure* 3, the method of tracing the brackets round the winding steps from the flyers. Supposing CD equal to their length, and AB equal to those of the flyers. Having divided CD in the same proportion as AB, make the ordinate *pm* equal to PM.

## HAND-RAILING.

The art of forming Hand-rails round circular and elliptic well-holes, without the use of the cylinder, is entirely new. Mr. Price, the author of '*The British Carpenter*,' is the first who appears to have had any idea of forming a wreath-rail. Subsequent writers have contributed little or nothing towards the advancement of this most useful branch of the Joiner's profession, and have contented themselves with the methods laid down by Price, which were very uncertain in their application; and, consequently, led to very erroneous results in the practice.

The first successful method of squaring the wreath, upon geometrical principles, was invented and published by Mr. Peter Nicholson, in 1792, in a work called '*The Carpenter's New Guide*,' a book well known to architects and workmen. No previous author seems to have had any idea of describing the section of a cylinder through any three points in space, making a mould to the form of the section, and applying it to both sides of the plank, by the principles of solid angles; so that, by cutting away the superfluous wood, the piece thus formed might have been made to range over its plan.

Since the first invention of the method, the author's experience and researches have produced many essential requisites, which were not thought of at first; so that this branch, as here presented, is now much improved.

The principle of projecting the rail furnishes the workman with a method by which he can ascertain, with great precision, the thickness of the plank out of which the rail must be cut. To do this in the most convenient way, the diagram must be made to some aliquot portion of the full size, which will supersede the necessity of laying it down on a floor. It must, however, be observed that the thickness of stuff found by this method is what will completely square the wreath or piece. But, as the rail is reduced from the square to an oval or elliptic section, much thinner stuff may be made to answer the purpose; so that, generally, for rails of the common size of $2\frac{1}{8}$ or $2\frac{1}{4}$ inches thick, instead of requiring a three-inch plank, one of two and a half may be made to answer the purpose.

1. The Hand-rail of a stair is that which is put up in order to prevent accidents, by falling into or through the well-hole.

2. The Prismatic mould, formerly used for forming the wreaths, and fitting the rail together, is now of no other use than merely to help the conception of the learner. In this case, we shall still be obliged to use the idea of such a prism, which was called by workmen a cylinder, whatever might be the form of the base or right section. But, as the word cylinder is used to define a geometrical solid, and has had the sanction of the learned for upwards of two thousand years, we must not use the word cylinder in two different senses without some word of qualification; as, otherwise, it will be

impossible to know which of the two bodies is meant. We shall therefore call the cylinder used by workmen *a cylindrome* or *working-cylinder.*

3. Supposing the working-cylinder to be covered with a thin pliable substance, as paper, and to be inserted in the well-hole, as if it were a newel, and the planes of the risers and treads to be continued, so as to intersect the covering; the indented line, formed by the intersections of the risers and treads, in the development of the covering, supposing it extended on a plane, is called the *envelope* of the well-hole.

4. The straight line formed on the envelope with the base of the cylinder is called the *base of the envelope.*

5. The straight line passing through the points of the external angles, on the development of the steps, is called the *line of nosings.*

## THE THEORY OF HAND-RAILING.

Suppose any line to be drawn on the surface of the working-cylinder, and the working-cylinder to be cut entirely through, from this line to the opposite surface, so that a straight line, passing through any point of the line, drawn perpendicular to the surface, will coincide with the section made by cutting the solid, through the line thus drawn; every such line will be parallel to the base of the working-cylinder.

Suppose that the upper portion of the working-cylinder, separated from the lower, to be removed, and the lower to be inserted in the well-hole; then, if the surface of separation coincide with the nosings of the steps, while the base rests on the floor; and, if we again suppose the whole to be elevated to a certain height without turning, so that the base may be parallel to the floor, the surface of separation will form the top of the hand-rail in the square; and the two vertical sides of the hand-rail will be a portion of the vertical surfaces of the working cylinder.

Again, suppose that, while the portion of the working-cylinder, thus formed, remains in the situation now described, another portion next to the top is again separated from the lower portion, but not removed, in such a

manner that the uppermost part may be every where of a certain thickness between the surfaces of separation; the upper part, thus separated, would exactly form the hand-rail in the square; and this the solid which we would wish to form, first in parts, and then to put the parts together, so as to constitute the whole solid *Helix,* as if it had been cut out of the solid of the working-cylinder.

The form of the solid helix, now defined, is called by workmen a square rail; the method of preparing the rail, in parts, of this form, is called the *squaring of the rail.*

The square rail is therefore contained between two opposite surfaces, which are portions of the surfaces of the working-cylinder, and two other winding surfaces, contained between each pair of curves of the helix.

The Plan of a Hand-rail is the space or area which the base of the working-cylinder would occupy on the floor. This area is therefore bounded by two equi-distant lines, on which each of the working-cylindric surfaces stand erect, and the breadth of the space between these two equi-distant lines is called the *breadth of the rail.*

The Story-rod is a rod of wood, equal in length to the height of the stairs, or the distance between the surface of one floor and that of another. It is divided into as many equal parts as the number of steps in the height of the story: its use is to try the steps as they are carried up.

For the conveniency of forming a square rail out of the least quantity of stuff, and in the shortest time, the rail is made in various lengths; so that, when joined together, the whole may form the solid intended.

If the rail thus joined be set in its true position, and if the joints be in planes perpendicular to the horizon, and to the surface of the working-cylinder, the joints are called *splice-joints.* But if each joint be in a plane perpendicular to one of the arrises, the joint is called a *butt-joint.*

It is evident that any portion of a hand-rail may be made of plank-wood of sufficient thickness and length: because such a portion of the rail may be considered as a portion of the working-cylinder, contained between two parallel planes, which may represent the faces of the plank; and the two

sections of the working-cylinder, made on these planes, will represent a mould to draw the same upon the surfaces of the plank: then, if the surrounding wood be cut away in the same manner, the vertical sides of the rail will be formed agreeably to the definitions which we have given.

A mould made to form a section of the working-cylinder is called a *face-mould.*

A mould made to cover one of the vertical surfaces of a square rail is called a *falling mould.* A falling mould made to cover the convex surface of the square rail is called the *convex falling mould;* and that which is made to fit the concave surface is called the *concave falling mould.* The form of the falling moulds can be ascertained by geometrical rules; and, consequently, if the proper portion of the falling mould be rightly applied to the rail-piece, when cut out of the plank, and if lines be drawn by the two edges of the falling mould, and the superfluous wood cut away, so as to be every where perpendicular to the surface of the working-cylinder, that portion of the rail will be formed.

The MITRE-CAP of a rail is a block of wood, turned to some agreeable figure, of a greater diameter than the breadth of the hand-rail. It is used in dog-legged stair-cases, for the purpose of giving a neat appearance to the termination of the rail, at a very little expense.

The SCROLL is the termination of the hand-rail of a geometrical stair, in the form of a spiral, and is placed above the curtail-step, which is made to correspond with the scroll.

BALUSTERS are vertical pieces fixed on the steps for supporting the hand-rail. In flights, the balusters are placed equi-distant, so that every step may have two balusters; and that one side of each baluster may be in the plane of each riser, and the whole thickness of each baluster so placed that it may stand within the solid of the riser.

In order to keep the hand-rail steady, and to provide against accidental violence, iron balusters must be inserted into the range, at equal distances, and strongly fixed to the steps. In common stairs, where wooden balusters only are used, the balusters are placed against the nosings, and let into

the step-board below; and, being fastened to the nosings with nails, will be very secure.

The Ramp, in a dog-legged and open-newel stair-case, is the upper end of a hand-rail adjoining to the newel, formed, on the upper side, into a concavity, but straight with regard to the plan.

A Swan-neck, in dog-legged and open-newelled stair-cases, is a portion of the rail, consisting of two parts, the lower being concave and the upper convex on the top, and terminating in a framed newel, so as to be parallel to the horizon.

A Knee, in a dog-legged and open-newelled stair-case, is the lower end of a hand-rail, next to the newel, formed either into a concavity on the upper side, or made to terminate upon the newel with a short level, mitred into the raking or sloping part of the rail, which follows the curvature of the steps.

The same part of a rail may therefore be both *ramped* and *knee'd;* that is, ramped at the upper end, and knee'd at the lower; or it may be *swan-necked* at the upper end, and *knee'd* at the lower.

When there is any sudden rise in the balusters, the top of the rail ought to be kept to the same height throughout, as nearly as possible; but, should the height of the steps lead the top of the rail to irregularity, in the curvature of the rail, the line of fall must be rendered agreeable, by taking away the angles, and reducing the whole to a uniform curve. These curves are called the *easings of the rail.* By this mean, the impediments which the hand might meet, in passing along the back of the rail, will be removed, instead of being suddenly interrupted at every junction. When the risers of three or more steps terminate in the same vertical line, in order to connect the lower and upper ends of the rail in the most agreeable manner, the intermediate part will require to be *ramped,* as is done in dog-legged stair-cases. But where not more than two risers terminate in the vertical line, the rail is frequently continued, so as to form an elbow in the intermediate part, in such a manner, that the top of the three parts thus connected may be all in one

plane; which will be as pleasant to the eye as it is convenient; since the parts, thus joined, may be cut out of the thinnest wood possible.

To fix the rail in such a position as to differ the least from being parallel to the line of nosings, or the string-board, the top over the upper part may be depressed half the height of a step, while that over the lower part may be as much elevated; so that, though the rail may not be entirely parallel with the line of the nosings, the lower part rising higher as it advances towards the intermediate part, or turn, and the upper part approaching nearer to the line of nosings, as it is more remote from that part, the whole appearance will be more agreeable to the eye.

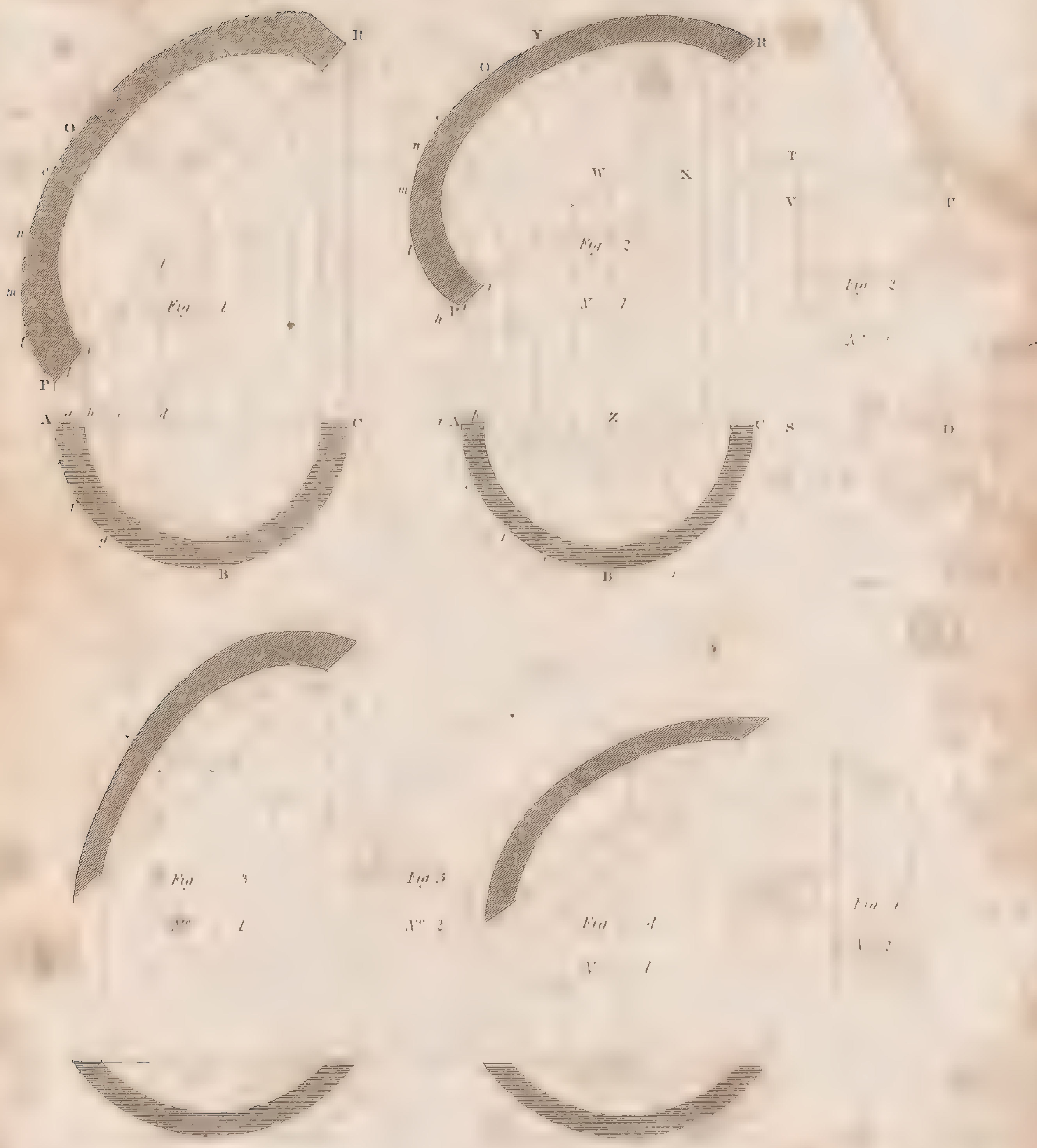
Where winders are necessary, and the well-hole very small, the top of the rail must be kept higher over the winders than over the straight part; as, otherwise, the person who ascends or descends will be in danger of tumbling over into the well of the stairs.

The rise of the rail, over the circular plan, cannot be regulated by geometrical principles, but must be left to the discretion of the workman. The rail ought not to be raised to any considerable degree over the winders, unless in very extreme cases, as it occasions not only a deformity in the fall of the rail, but a great inconvenience to the workman, by obliging him to prepare the semi-circular part of the rail to different face-moulds; whereas the same moulds might be alike applied to both parts of the rail. Where this practice is necessary, the easing of the rail, at the upper end, will be over the circular part of the plan; while that at the lower end will be entirely on the straight part below the winders; and thus, as it occasions the upper part to have less slope than the lower, so it occasions also the face-mould of the upper part to be considerably shorter than that of the lower part.

To FIND THE SECTION OF A CYLINDER, when it is cut by a plane perpendicular to a given plane, parallel to the axis of the cylinder. (See *Fig.* 1, *pl.* LVII.)

Let ABC, (*fig.* 1,) be the base, and ACRP the plane parallel to, or passing along, its axis, and PR the line of section.

# HAND RAILING

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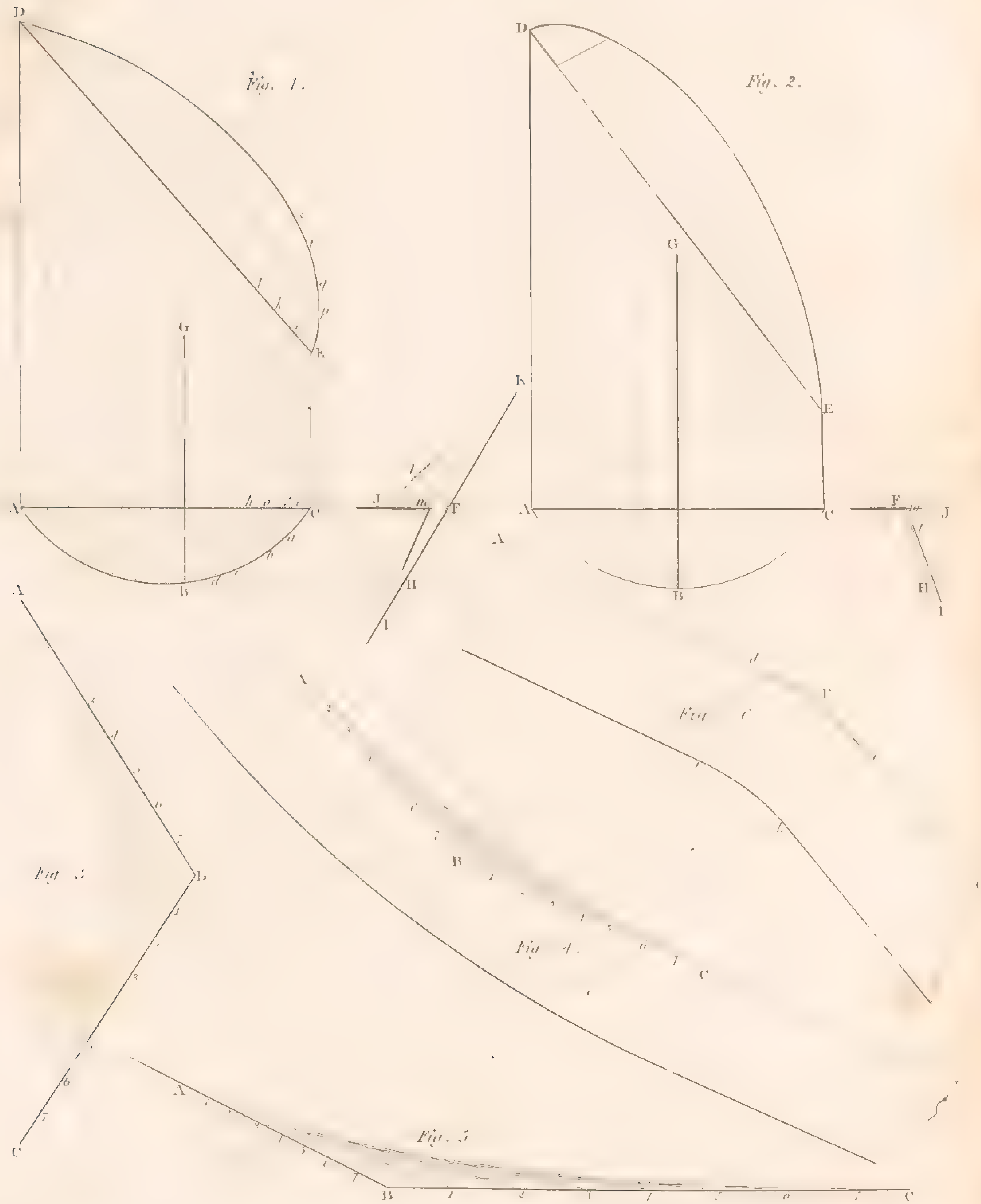


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In ABC take any number of points, *e,f,g*, and draw the lines *he, if, jg*, &c., parallel to AP or CR, cutting AC in *a, b, c, d*, &c., and PR in *h, i, j, k*, &c.: perpendicular to PR draw *hl, im, jn, ko*, &c. Make *hl, im, jn*, &c., respectively equal to *ae, bf, cg*, &c. Through all the points *l, m, n, o*, &c., draw a curve, which will be the section required.

If the cylinder be hollow, the inner curve will be described in the same manner.

When the plane of section makes an acute angle, as in *fig*. 2.

Let STU, (*fig*. 2, No. 2,) be the angle which the cylinder is to be cut at. Draw DU parallel to ST, at that distance from ST which is equal to the radius of the semi-circular base. Draw B*r* parallel to AC. From the centre, Z, of the semi-circle, draw ZW, parallel to AP or CR, cutting PR in W. Draw WX parallel to AC, and draw X*r* parallel to AP or CR. Join Z*r*. Draw XY perpendicular to PR. From W, with the radius Z*r*, describe an arc, cutting XY at Y, and join WY.

In the arc ABC take any number of points, *e,f,g*, &c., and draw the ordinates *ea, fb, gc*, &c., cutting AC in *a, b, c*, &c. From the points *a, b, c*, &c., draw *ah, bi, cj*, &c., parallel to AP or CR, cutting PR in *h, i, j*, &c. Draw *hl, im, jn*, &c., parallel to WY, and make *hl, im, jn*, &c., respectively equal to *ae, fb, cg*: then, through all the points *l, m, n*, &c., draw a curve, and it will be the section required.

If the cylinder be hollow, the inside curve will be traced in the same manner, and from the same parallels Z*r* and WY, and by the very same ordinates; only observing the points where the inner semi-circle cuts these ordinates.

Upon the principle here shown, the sections of *figures* 3 and 4 are to be found: both these figures are segments of cylinders; *fig*. 3 being cut at an obtuse angle, and *fig*. 4, at an acute angle.

To find the Section of a Cylinder, so as to pass through three given points in its surface, (*figures* 1 and 2, *pl*. LXIV.)

Let the seats of the three given points be ABC, in the base ABC of the cylinder, and let ADEC be the plane standing upon AC perpendicularly.

Join the points A and C, by the straight line AC, and produce AC to F, and draw BH parallel to AF. Draw AD, BG, and CE, perpendicular to AF or BH. Make AD equal to the height of the point, over its seat A, BG equal to the height of the point over its seat B, and CE equal to the height of the point over its seat C. Join DE and produce DE to F. Draw GH parallel to DF; and, through the points H and F, draw FI.

In AF take any point, J, and draw JI perpendicular to AF; and draw JK perpendicular to DF. From J, as a centre, with the radius J*l*, describe an arc cutting JK at *l*. From J, with the radius J*l*, describe the arc *lm*, cutting AF in *m*, and join *m*I.

In the base ABC take any number of points, *a, b, c, d,* &c., and draw the lines *ae, bf, cg, dh,* &c., parallel to FI, cutting AF in the points *e, f, g, h,* &c.

Draw *ei, fj, gk, hl,* &c., parallel to AD, BG, or CE, cutting DE in *i, j, k, l,* &c. Through the points *i, j, k, l,* draw *ip, jq, kr, ls,* &c., and make *ip, jq, kr, ls,* &c., each respectively equal to *ea, fb, gc, hd,* &c.; then, through the points E, *p, q, r, s,* &c., draw a curve, which will be the section of the cylinder as required.

The angle J*m*I is that which the plane of section now found, makes with the vertical plane ADEC.

The whole of the art of hand-railing depends on finding the section of a cylinder to pass through three given points on its surface; the reader is therefore requested to understand this thoroughly, before he actually commences his study upon hand-rails; for, if the principles are not comprehended, he will always be in difficulties, and liable to spoil his work.

The hand-rail of a stair is made in various lengths, and each portion is got out upon the principle of its being the section of a cylinder, and is cut out of a plank not exceeding two and a half inches in thickness. It would not be practicable to get a rail out in pieces for more than a quarter of a circle: a portion of the rail got out in one length, answering to the semi-circumference of the plan, would require a very great thickness of stuff; how much more then would a whole circumference require? for the thickness of stuff increases in a much more rapid ratio than the circumference.

# HAND RAILING.

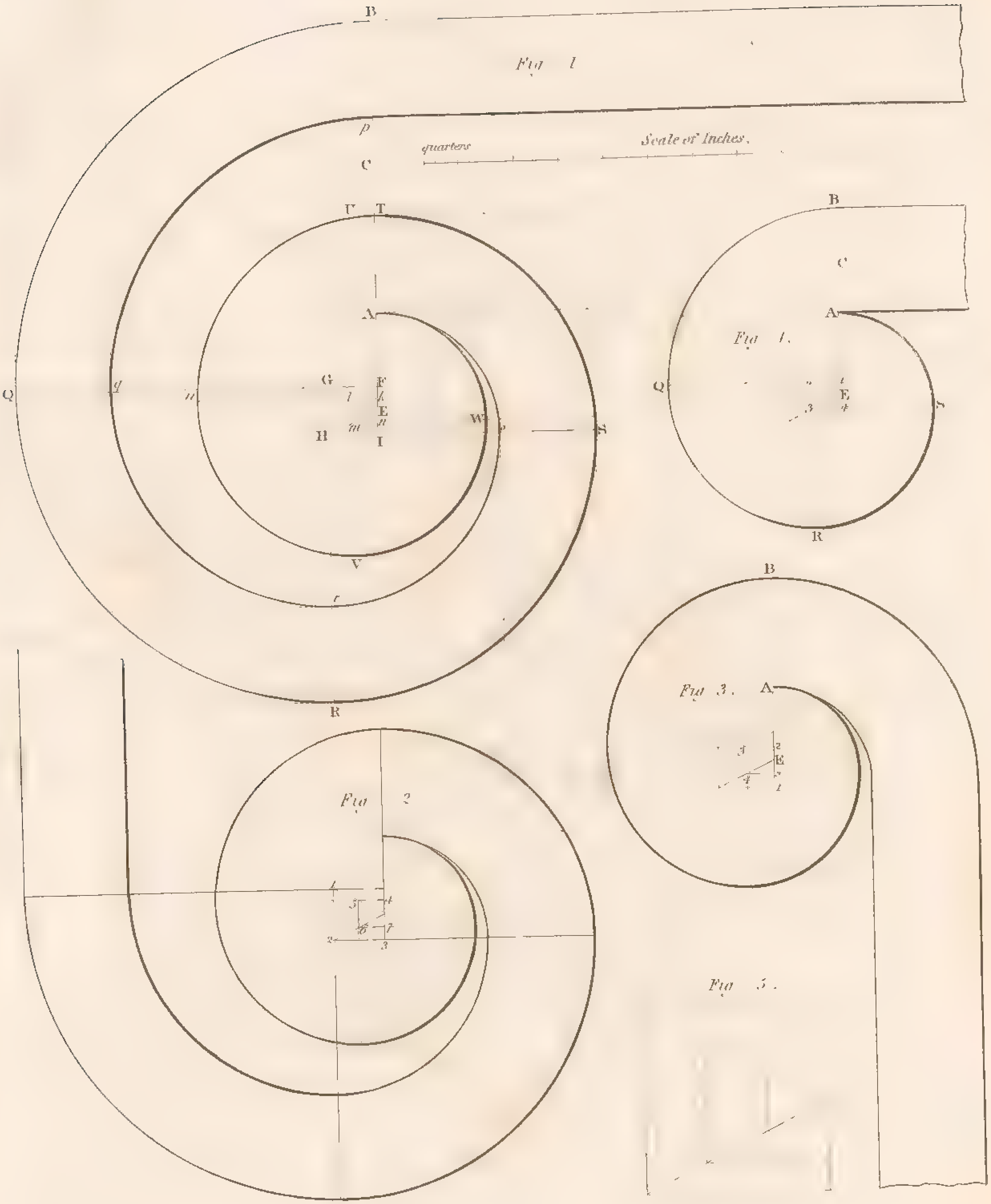


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*Figure* 3 (*pl.* LVIII) is the method of drawing a curve, which shall touch two straight lines, AB, BC, in two given points A and C.

Divide AB, BC, each into any number of equal parts; beginning at A and B, draw the straight lines 11, 22, 33, 44, &c., through the corresponding points of division, and the lines thus drawn will be tangents to the curve.

The reducing of a piece of wood from an angle to a round is called by workmen the *easing of the angle.*

*Figure* 4 is an application of this to the hand-rail of a stair.

*Figure* 5 shows how the same may be done when AB and BC are unequal.

*Figure* 6 is another method of easing the rail at an angle. Let ABC be the angle, and let it be required to round it in a very small degree.

Make B*d* equal to B*e*. From *d* draw *df* perpendicular to AB, and *ef* perpendicular to BC. From *f*, with the radius *fd* or *fe*, describe the arcs *de* and *gh*, which will form what workmen call a *knee* in the rail.

## THE METHOD OF DRAWING SCROLLS FOR HAND-RAILS, ANSWERING TO EVERY DESCRIPTION OF STAIRS. (*pl.* LIX.)

First, Let it be required to describe a spiral to any number of revolutions, between two given points, in a given radius.

Let E (*fig.* 1) be the centre, EB the given radius, and let the two given points be A and B, between which it is required to draw any number of revolutions.

Divide AB into two equal parts, in the point C, and divide AC or CB into equal parts, consisting of one part more than the number of revolutions; then, in the line EB, make EF and EI each equal to the half of one of these parts; then, upon FI, construct the square FGHI. Draw GE and HE. Divide GE and HE into as many equal parts as the spiral is to have revolutions; through these points construct as many squares, of which one side will be in the line FI, and the other sides terminate in the lines GE and HE; then the angular points of the outer square will be the centres for the first revolution, the angular points of the next less square the centres for the second

revolution; the angular points of the next less square will be the centres for the third revolution, and so on; one quadrant of a circle, which is one quarter of a revolution, being described at a time.

To apply this to the present example, which is to have two revolutions, divide, therefore, AB into two equal parts, as before, in the point C, and divide AC or CB into three equal parts; that is, into one part more than the number of revolutions. Make EF and EI each equal to half a part, and on FI describe the square FGHI. Join GE and HE, and divide GE or HE into two equal parts, being as many as the number of revolutions, and complete the inner square *klmn*. Produce FG to Q.

From the centre, F, with the distance FB, describe the quadrant BQ.

Produce GH to R; then, from the centre G, with the radius GQ, describe the arc QR.

Produce HI to S; then, from the centre H, and, with the radius HS, describe the arc RS.

From the centre I, with the radius IS, describe the quadrant ST; which finishes the first revolution of the spiral.

Again, produce *kl* to U, *lm* to V, *mn* to W; then, from *k*, with the radius *k*T describe the arc TU; from *l*, with the radius *l*U, describe the arc UV; from *m*, with the radius *m*V, describe the arc VW; from *n*, with the radius *n*W, describe the arc WA, which will complete the second revolution, and terminate in the point A, as required.

To draw the second spiral, and thereby to draw the scroll complete.—In the straight line EB set B*p* towards E, equal to the breadth of the rail; then from F, with the radius F*p*, describe the arc *pq*; from G, with the radius G*q*, describe the arc *qr*; from H, with the radius H*r*, describe the arc *rs*; from I, with the radius I*s*, describe the arc A*s*, which will complete the scroll.

The whole breadth of this scroll, now drawn, is about twelve inches and five-eighths of an inch, and is intended for a very large step. The breadth of the scroll, *fig.* 2, is ten inches and a half; the breadth of the next scroll, not shown here, is eight inches and three-eighths of an inch; which will be a proper breadth for an ordinary sized step. The breadth of *fig.* 3 is six

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inches and seven-eighths of an inch; which is applicable to hand-rails where there is very little room.

All these scrolls are only portions of the great scroll, *fig.* 1, and show that one mould may be made so as to answer any number of revolutions: these scrolls are all drawn from the same centres as that of *fig.* 1. *Fig.* 1 consists of eight quadrants; *fig.* 2, of seven quadrants; the other, consisting of seven quadrants, is not shown, from want of room. *Fig.* 3 consists of five quadrants; and *fig.* 4, of four quadrants, and may be drawn, independent of *fig.* 1, by the very same rule, which must be adapted to one revolution: divide AB into two equal parts, in the point C, as before. Divide AC into two equal parts, that is, into one part more than the number of revolutions; because it is to consist of only one revolution. Then, making E the middle of the side of the square, describe the square 1234. From the centre 1, with the radius 1B, describe the arc BQ; from the centre 2, with the radius 2Q, describe the arc QR; from the centre 3, with the radius 3R, describe the arc RS; and, from the centre 4, with the radius 4S, describe the arc SA, which will complete the scroll, as required.

### TO FIND THE MOULDS FOR EXECUTING A HAND-RAIL.

Let *fig.* 1, *pl.* LX, be the plan of the rail; AB and DE being the straight parts; BCD the circular part, which is divided into equal parts by the point C; and, consequently, BC and CD are each quadrants.

### TO CONSTRUCT THE FALLING MOULD.

In *fig.* 2 draw the straight line AB; and through A draw CE, perpendicular to AB. Make AC and AE each equal to the stretch out of the quadrant BC or CD, (*fig.* 1,) together with the breadth B*g* or D*h* of a flyer. Draw CD (*fig.* 2,) parallel to AB. Make CD equal to the height of twelve steps; that is, equal to the ten winders, together with the breadth of the two flyers, one on each side of the winders. Make E*h* equal to the breadth of one of the flyers, and draw *hi* perpendicular to CE, and make *hi* equal to the

height of a step. Join *i*E. In like manner, in the straight line CD, make D*j* equal to the height of a step. Draw *jk* parallel to CE, and make *jk* equal to the breadth of one of the flyers. Join D*k*, and *ki*.

As it is customary with some workmen to raise the rail higher upon the winders than upon the straight part; and, as this is altogether arbitrary, draw *lm* parallel to *ki*, at such a height as the workman may think proper. Make *ln*, *no*, *mp*, each equal to *m*E; then ease or reduce each of the angles *lno* and *pm*E to curves *nwo*, *pq*E; then draw a line *rstuv* parallel to D*nwopq*E, comprehending a distance equal to the depth of the rail, and this completes the falling mould of the rail.

### TO FIND THE FACE-MOULD OF THE RAIL.

It is customary to execute a small portion of the straight rail along with the wreath, or twist, for each quadrant of the rail; and, as this distance is arbitrary, set off B*e* and D*f*, *fig.* 1, each equal to three inches. Transfer this distance to *hx* and *ky*, *fig.* 2.

In *fig.* 2, draw *xu* perpendicular to CE, cutting the upper edge of the falling mould at *u*; also draw *yz*B* perpendicular to CE, cutting the under edge of the falling mould at *n*, and the upper edge of the same at *z*.

Through any point B* draw B*B, parallel to CE, and divide A*x* B*B each into two equal parts at the points B, A. Draw BC perpendicular to CE, cutting the top of the rail at C, and draw A*o* perpendicular to B*B, cutting the under edge of the rail at *o*.

In *fig.* 3 lay down the plan for one quarter of the rail, *fig.* 1, taking in the straight part. ABC, *fig.* 3, being the quadrant, and CD the straight part of the rail.

It is found that, if the part of the rail over the plan ABCDFE, *fig.* 3, were actually executed, that a plane would touch the three points of the rail in the perpendiculars erected upon the plan EBD.

Join EF, (*fig.* 3,) and produce EF to G. Draw EH, BI, and DK, perpendicular to EG. Make EH equal in height to A*t*, *fig.* 2; BI equal to BC,

*fig.* 2; and DK equal to *xu*, *fig.* 2. Join ED, and produce ED to L. Draw BM parallel to EL. Join HK, and produce HK to L; and draw IM parallel to HL. Join ML, and produce ML to meet EG in G. In GM, take any point, *q*, and draw *pq* perpendicular to EG, cutting EG in *p*; and draw *pr* perpendicular to HG. From G, with the radius G*q*, describe an arc cutting *pr* in *r*; join G*r*. In the curve CA take any number of points *a*, *b*, *c*, &c. and draw *ad*, *be*, *cf*, &c., parallel to GM, cutting EG in the points, *d*, *e*, *f*, &c.

Draw *dg*, *eh*, *fi*, &c., perpendicular to EG, cutting HG in the points *g*, *h*, *i*, &c. Draw *gk*, *hl*, *im*, &c., parallel to G*r*. Make *gk*, *hl*, *im*, &c. each respectively equal to *da*, *eb*, *fc*, &c; and, through all the points *k*, *l*, *m*, &c., draw a curve, which will give the outer edge of the falling mould. The inner edge, *q*, *r*, *s*, &c., is found in the very same manner: viz. by transferring the ordinates *dn*, *eo*, *fp*, &c. to *gq*, *hr*, *is*, &c., and drawing the curve *qrs*, which is the inner edge of the falling mould.

Though the same principle serves to find the straight part of the rail, as well as the circular part, the straight part of the face-mould will be more accurately ascertained thus: Let FD (*fig.* 3) be the end of the straight part on the plan, and C*n* the line which divides the straight and circular parts of the rail.

Through the points *n*CD draw the ordinates *nd*, C*v*, and D*z*, parallel to GM, cutting EG in the points *d*, *v*, *z*. Draw *dg*, *vA*, and *zB*, parallel to EH, cutting HG in the points *g*, *A*, *B*. Draw *gq*, *Au*, and *Bt*, parallel to G*r*. Make *gq* equal to *dn*, *Au* equal to *v*C, and B*t* equal to *z*D. Draw F*C* parallel to EH, cutting HG in *C*. Join *Cq* and *Ct*. Draw *qu* parallel to *Ct*, and *tu* parallel to *Cq*; then *Cqut* will be that portion of the face-mould answering to the straight part *n*CDF on the plan.

The joint-line of the face-mould will be very accurately found thus:

Produce (*fig.* 3) GE to *w*. Draw A*w* parallel to MG, and *wx* parallel to EH, cutting GH produced in *x*. Draw *xy* parallel to G*r*, and make *xy* equal to *w*A; and by this method the whole of the face-mould is found in the most accurate manner.

To show the manner in which *fig.* 4 is determined, it is proper to observe here that the operation is inverted for the conveniency of finding the mould from the under side of the falling mould, instead of from the upper side.

In *fig.* 4, draw the plan ABDFE, and let the resting points be E, B, D. Join EF, and produce EF to G. Draw DK, BI, and EH, perpendicular to EF. Make DK equal to *B*n fig.* 2; BI equal to *Ao, fig.* 2, and EH equal to B*D*, *fig.* 2. Join ED, and produce ED to L; join HK, and produce HK to L. Draw BM parallel to EL, and IM parallel to HL. Join ML, and produce ML to G, and join GH. In GE take any point, *p*, and draw *pq* perpendicular to GE, cutting GM in *q*. Draw *pr* perpendicular to HG. From L, as a centre, with the radius L*q*, describe an arc, cutting *pr* at *v*, and join G*v*: then complete the falling mould as before.

TO FIND THE MOULDS FOR EXECUTING A HAND-RAIL, WITH FOUR WINDERS IN ONE QUARTER, THE OTHER BEING FLAT ROUND A SEMI-CYLINDRIC WELL-HOLE, HAVING FLYERS ABOVE AND BELOW.

*To find the Falling Mould.* (*fig.* 1, *pl.* LXI.)—Draw the straight line JI, in which take any point, *d*, and draw *d*C perpendicular to JI. In *d*C make *dt* equal to the greater radius of the rail, and, through *t*, draw *ab* parallel to JI. From the centre *t*, with the radius *td*, describe the semi-circle *adb*. In *t*C make *t*U equal to *tb*, together with three-fourths of *tb*. Join U*a* and U*b*. Produce U*a* to meet JI in T, and U*b* to meet JI in H. In JI make HI equal to the breadth of one of the flyers. Draw HG perpendicular to HI, and make HG equal to the height of a step, and join GI. Make TJ equal to the breadth of two of the flyers.

Draw JN perpendicular to JI. In JN make JK equal to the height of a step, K4 equal to the height of four steps, KL equal to the height of five steps, KM equal to the height of six steps, and KN equal to the height of seven steps. Draw 4*f* parallel to JI, meeting *d*C in *f*. Draw L*e* parallel to JI, and T*e* perpendicular to JI. Draw M*h* parallel to L*e*, and make M*h*

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equal to the breadth of a step. In L*e* make L*g* and *ge* each equal to the breadth of a step; and join N*h* and *he*. Join also *hf* and *f* G. Produce *hf* to *w*, and draw *w* Q parallel to *f* G. In the lines *wh* and *w* Q make *wu* and *wv* each equal to the hypothenuse of a step. Draw the curve *uv* to touch the straight lines *wh* and *w* Q, in *u* and *v*. The same being done below, where the two straight lines join at Q, the crooked line N*huv*SZ will be the under edge of the falling mould. From the under edge of the falling mould draw a line, at the distance of two inches above it, and the falling mould will be complete.

*To find the Face-Mould.* (*fig.* 2.)—Here *napc* is the convex side of the rail, being one quadrant, and *pc*, a tangent at *p*, being a portion of the straight part.

Through C, *fig.* 1, draw AC perpendicular to *d*C, and make CA equal to the stretch out or development of the curve-line *cpan*, *fig.* 2. Let *d*C intersect the under edge of the falling mould in X. Bisect AC in B, and draw BP and AO parallel to CX, meeting the under edge of the falling mould in the points P, O.

Having completed the inner line of the plan, *fig.* 2, draw the chord-line *eg*. Draw the lines *ef*, *ab*, *cd*, perpendicular to *eg*; *ab* being drawn through the centre *q*. Make *ef*, *fig.* 2, equal to CX, *fig.* 1; *ab*, *fig.* 2, equal to BP, *fig.* 1; *cd*, *fig.* 2, equal to AO, *fig.* 1. In *fig.* 2, join *ec*, and draw *al* parallel to *ec*. Join *fd*: and produce *fd* to meet *ec* in *m*. Draw *bl* parallel to *fm*, and join *lm*, which produce to *g*. In *lg* take any point, *k*, and draw *ki* perpendicular to *eg*, meeting *eg* in *i*. Join *fg*; and draw *ik* perpendicular to *fg*. From *g*, with the radius *gk*, describe an arc intersecting *ih* in *h*; and join *gh*.

In *eg* take any point, *r*. Draw *rt* parallel to *gl*, intersecting the inner curve of the plan of the rail in *s*, and the outer curve in *t*. Draw *r*R parallel to *ef*, meeting *fg* in R, and RT parallel to *gh*. In RT make RS equal to *rs*, and RT equal to *rt*; then will S be a point in the concave curve of the face-mould, and T a point in the convex curve of the face-mould. In the same manner we may find as many points, and by this means complete the whole face-mould.

In the same manner, by means of the three lines DX, ER, FS, *fig.* 1, we may construct the face-mould, *fig.* 3, in every respect similar to that in *fig.* 2.

Then the face-mould, *fig.* 3, applies to the lower half of the winders, and *fig.* 2, to the upper half.

## TO FIND THE MOULDS FOR A SEMI-CIRCULAR STAIR WITH A LEVEL LANDING.

*To construct the Falling Mould.* (*fig.* 1, *pl.* LXII.)—Draw the straight line MN and IL perpendicular to M, intersecting MN in K. From K, with a radius equal to that of the convex side of the rail, describe the semi-circle MIN. Make KL equal to the radius, together with three-quarters of it. Join LM, and produce LM to B; and join LN, which produce to C: then BC is equal to the development of the semi-circumference of the winders. Proceed and complete the falling mould as in the former cases. In this, FHG is the section of the lower flyer, DAS the section of the upper flyer, the whole height being three steps; the middle part of the falling mould between AD and HF is level.

*Figures* 2 and 3 exhibits the method of tracing out the face-mould. In *fig.* 2 produce the straight line *a*5 to *d*; and, through the centre Y, draw Y*e* parallel to *ad*. Draw *ac* and YQ perpendicular to *ad* and Y*e*. Make the angles *acd* and YQ*e* each equal to the angle ASD or HGF, *fig.* 1. Join *de*. Then, to find any point in the face-mould. In Y*e* take any point, *m*, and draw *mu* parallel to YQ, meeting Q*e* in *u*. Find the line *ef*, as in the description of *plate* LXI; draw *u*E parallel to *e*F, and *m*5 parallel to *ed*, intersecting the concave side of the plan in *l*, and the convex side in 5. Make *u*M equal to *ml*, *u*E equal to *m*5; then M is a point in the inside curve of the face-mould, and E a point in the outside curve: a sufficient number of points being thus found, the whole face-mould may be completed; and *fig.* 3, in the same manner.

*Plate* LXIII shows the falling moulds and face-moulds for a rail, where the opening is only three inches; and though the operation of finding the moulds

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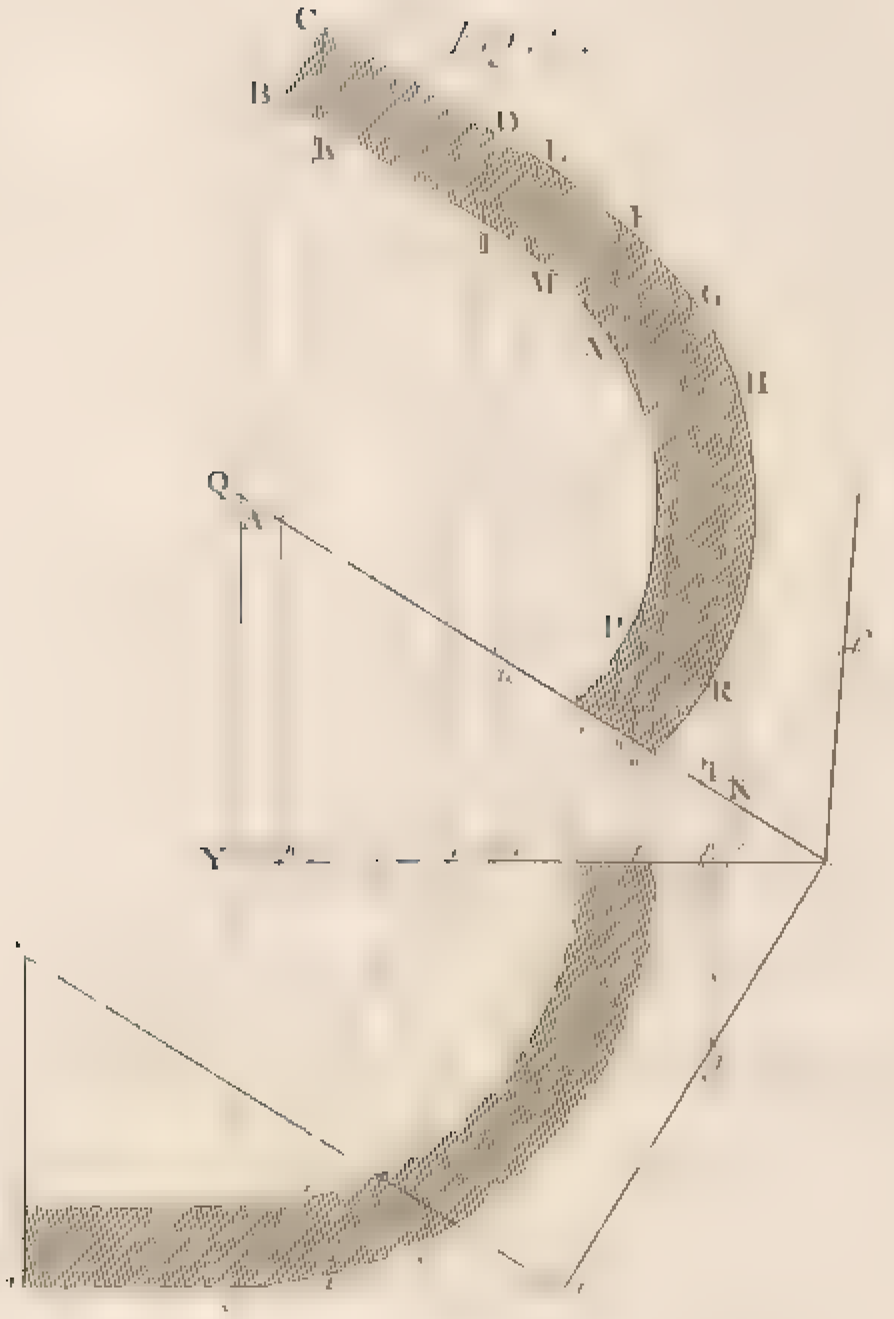


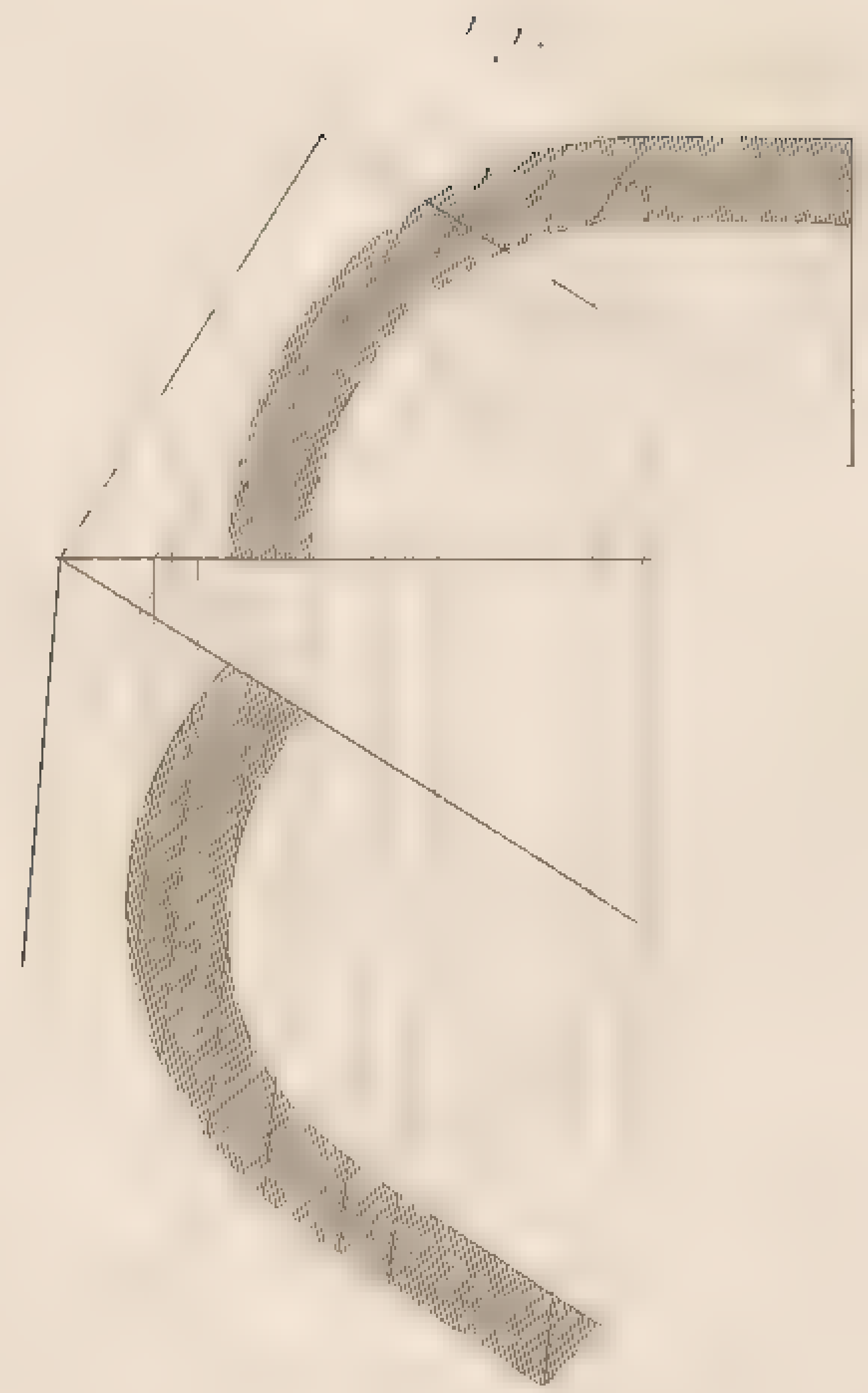

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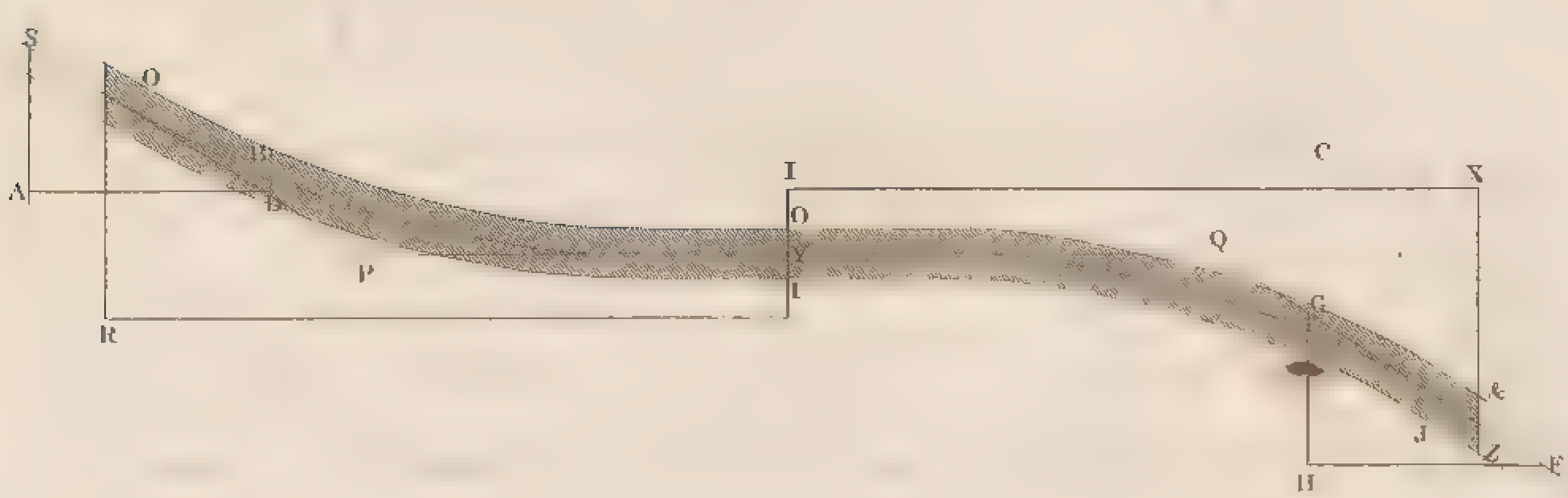


Drawn by M.A.Nicholson. Engraved by W.

London, Published by Tho.s Kelly, 17 Paternoster Row, Feb.y 28, 1824.

# HAND RAILING.


Engraved by W. Symns

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for executing the rail is exactly the same as has been shown, their forms are entirely different.

The face mould, (as represented in *pl.* LXIV,) though last found, must be first applied to the plank, in the following manner. First, bevel the edge of the plank, according to the angle A*m*I, shown in *fig.* 1 *and* 2, of the sections of a cylinder. Near the upper end of the bevelled edge apply the angle ADF; then apply one extreme point of the inner edge of the face-mould to the top of the plank, and bring it to that point of the arris* where the line intersects, and bring the other extreme point to the same arris; then, the under side of the face-mould coinciding with the face of the plank, draw a line by each edge of the mould. Apply the mould to the under side of the plank in the same manner: then cut away the superfluous wood on the outside of the lines drawn on the plank; which being done, apply the falling mould to the convex side of the piece thus formed.

It is not easy to give such directions as to make the workman perfectly understand the application of the face-mould and falling-mould; but, by a little practice, a perfect knowledge of the terms, and ruminating upon the subject, the directions here given will conduct him through every difficulty. Without putting one's ideas in a proper train, the plainest directions that can be written, except on the most self-evident subjects, may be mistaken.

*To find the Falling and Face-Moulds for an Elliptical-planned Stair, where the Steps next to the Well-hole are equally divided.*

Let ABCD (*pl.* LXV, No. 1,) be the seat of the external side of the rail, and *abcd* the seat of the internal side; these two curve lines comprehending between them the thickness of the rail.

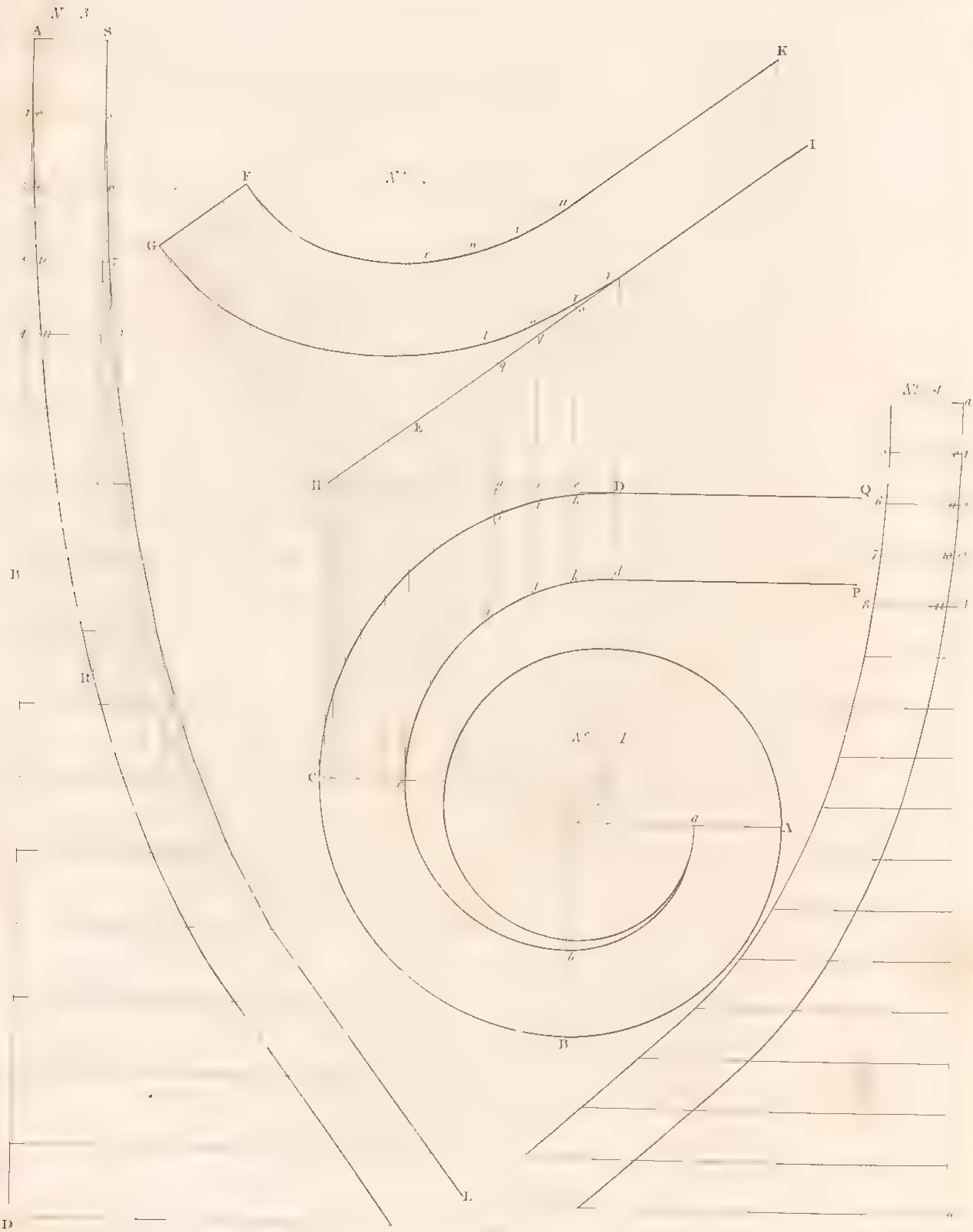
In order to cut the rail out to the greatest advantage, so as to waste the least stuff or wood, it is got out in three lengths AB, BC, CD; the joints being represented by B*b*, C*c*, D*d*, the scroll and the adjoining part being formed of a separate piece.

* The explanation of *Arris*, and other terms, is to be found in the next Chapter.

The first thing to be done, as in all other cases of this kind, is, to lay down the falling mould. For this purpose, let AB, No. 2, be the stretch out of the line AB; and make AB, BE, in the proportion of any number of steps to their height, and draw the line AE. Then draw *ae*, at such a distance from AE, that AE, *ae*, may comprehend between them the thickness of the rail. In like manner, draw BC, No. 3, and make BC to CF as the tread of any number of steps next to the well-hole is to their height, and draw *bf* parallel to BF, so that BF and *bf* may comprehend between them the entire thickness of stuff.

Bisect AB, No. 2, in G, and draw GH perpendicular to AB, cutting AE in the point H. Bisect BC, No. 3, in the point I, and draw IJ perpendicular to BC, cutting BF in J. Divide the length of the curve AB, No. 1, into two equal parts, in the point K; also divide the curve BC into two equal parts in the point L, and divide the curve CD into two equal parts, in the point M; then the points *a*, K, B, are the three resting points for the portion of the rail over AKB; three resting points of the rail, over BLC, are *b*, L, C; and the three resting points of the rail, over CMD, are *c*, M, D. Now, according to the falling mould, laid down at Nos. 2 and 3, the height at A, No. 2, is nothing; therefore, the height upon A, No. 1, is nothing: the height of the rail upon the point K, No. 1, is equal to the line GH, No. 2; and the height upon the point B, No. 1, is equal to the straight line BE, No. 2. Again, since in the falling mould, No. 3, the height upon B is nothing, so the height upon B, for the rail over its seat BLC, is nothing; the height upon L is the line IJ, and the height upon C is the straight line CF. The heights upon the points *c*, M, D, of the rail over CMD are the same as the heights upon the points *a*, K, B, of the rail over AKB.

Therefore, with the heights GH, BE, No. 2, find the intersections BN, No. 1, of a plane that would pass through the point *a*, and through the upper extremities of the lines erected upon K and B: next find CO, the intersection of a plane that would pass through the point *b*, and through the upper extremities of the lines standing upon L and C, and find DP, the intersection

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of a plane passing through the point *c*, and through the lines standing upon M and D.

Draw any line, QN, in No. 1, perpendicular to BN. Draw any line, OS, perpendicular to CO, and draw any line, PU, perpendicular to DP. Draw AR perpendicular to QN, cutting QN in Q; draw BT perpendicular to OS, cutting OS in S; and draw CV perpendicular to PU, cutting PU in U. Make QR equal to BE, ST equal to CF, and UV equal to BE. Join NR, OT, and PV. The moulds, Nos. 4, 5, 6, being traced in the usual manner, are applied to the plank, as at No. 7, where the edge and the two adjacent sides are stretched out. The moulds are usually traced, as at No. 8; but this position will evidently give the same thing as the method here taken, exhibited in Nos. 4, 5, 6.

*To find the Face and Falling Moulds of the Scroll of the Hand-rail.*

Place the edge DH, (*pl.* LXVI,) of the pitch-board DHI, upon the side of the shank of the scroll, as exhibited in No. 1 and No. 2.

In DH take any number of points, *e*, *f*, *g*, &c.; and through these points draw lines, perpendicular to DH, cutting the convex edge of the scroll in *h*, *i*, *j*, and the concave edge in the points *k*, *l*, *m*, &c. Produce the lines *ke*, *lf*, *mg*, &c., to meet the other edge, HI, of the pitch-board in *o*, *p*, *q*. Draw the straight lines *orv*, *psw*, *qtx*, perpendicular to HI, and the distances *ov*, *pw*, *qx*, &c., respectively equal to *ek*, *fl*, *gm*, &c.; then, through all the points, *u*, *v*, *w*, *x*, &c., draw a curve.

Again, make *or*, *ps*, *qt*, &c., respectively equal to *eh*, *fi*, *gj*, &c., and through the points *n*, *r*, *s*, *t*, &c., draw a curve, and the two curved parts of the face-mould will be completed. Draw *c*E, CH, and D*n*, perpendicular to HD, meeting the edge HI of the pitch-board in the points E and *n*. Draw HG, EF, *nu*, perpendicular to HI. Make HG equal to HC, and draw GF parallel to HI; also make *nu* equal to D*d*, and draw *u*K parallel to HI; then the whole of the face-mould will be completed. The part I*nu*K is termed the *shank of the face-mould*, the same as the part P*d*DQ is termed the *shank of the plan of the scroll*. The part C*cd*PQDC is got out of the plank by means

of the face-mould, by drawing the pitch-line on the edge of the stuff, then applying the mould, No. 2, to both sides of the plank, so that the same point of the face-mould may agree with the pitch-line, while the shank is parallel to the edge of the plank; then, the stuff being cut away, the piece, thus formed, being set up in its due position, will range to the plan.

*The Falling Moulds for the concave and convex Sides of the Rail,* are to be found as follows:

Suppose now that the rail is to have a continued fall to the point A, see the plan, No. 1. Stretch out the curve ABCD, No. 1, and draw the straight line AD, No. 3, and make AD, No. 3, equal to the curve line ABCD, No. 1. Apply the angular point of the pitch-board to some convenient point, B, in the line AD, No. 3, so that the edge may be on the line AD; then the other edge, LB, will form an angle, LBA, with AD. Draw AS perpendicular to AD, and make AS equal to the thickness of the scroll. Draw SR parallel to AD, cutting BL in R: ease off the angle LRS, by means of a parabolic curve; and this being done, will form the upper edge of the falling mould, for the convex side of the rail: then, through the point A, draw a curve line parallel to the upper curve; and thus the whole of the outside falling mould will be completed.

The inside falling mould will be found as follows: take the stretch out of the curve *abcd*, No. 1, and draw the straight line *ad*, No. 4, which make equal to the said curve. Divide AD, No. 3, and *ad*, No. 4, each into the same number of equal parts, the more the truer the work will be effected. We shall here suppose that sixteen equal parts will be sufficient; therefore each of the lines AD, *ad*, being divided into sixteen parts, at the points 1, 2, 3, 4, &c. Through all the points 1, 2, 3, 4, &c., No. 3, draw lines perpendicular to AD, cutting the upper curve at the points 5, 6, 7, 8, &c. and the under curve at the points, 9, 10, 11, &c. Again, through the points 1, 2, 3, 4, in the line *ad*, No. 4, draw perpendiculars 1-5, 2-9-6, 3-10-7, 4-11-8, &c. Make 1-5, 2-6, 3-7, 4-8, &c., in No. 4, respectively equal to 1-5, 2-6, 3-7, 4-8, &c., No. 3; then, through all the points 5, 6, 7, 8, &c.,

draw a curve; also draw *as*, in No. 4, perpendicular to *ad*, and join the point *s* to the curve: this being done, will complete the upper edge of the falling mould, for the concave side of the rail; then, through the point *a*, draw another curve; which, being done, will form the under line of the said falling mould.

The falling mould, No. 3, is applied to the convex side of the piece of stuff; and the other mould, No. 4, to the convex side of the said piece. The joint is made at the line C*c*, and the remaining part of the scroll is made out of a single level block; but part of each falling mould, No. 3 and No. 4, is used as far as the line A*a*; the remaining part of the block to the line A*a*.

# CHAPTER IV.

## AN EXPLANATION OF TERMS, AND DESCRIPTION OF TOOLS, USED IN CARPENTRY AND JOINERY.

### 1.—TERMS USED IN CARPENTRY AND JOINERY.*

Abutment.—The junction or meeting of two pieces of timber, of which the fibres of the one extend perpendicular to the joint, and those of the other parallel to it.

Arris.—The line of concourse or meeting of two surfaces.

Back of a Hand-rail.—The upper side of it.

Back of a Hip.—The upper edge of a rafter, between the two sides of a hipped roof, formed to an angle, so as to range with the rafters on each side of it.

Back-Shutters or Back-Flaps.—Additional breadths hinged to the front shutters, for covering the aperture completely, when required to be shut.

Back of a Window.—The board, or wainscoting between the sash-frame and the floor, uniting with the two elbows, and forming part of the finish of a room. When framed, it has commonly a single panel, with mouldings on the framing, corresponding with the doors, shutters, &c., in the apartment in which it is fixed.

Basil.—The sloping edge of a chisel, or of the iron of a plane.

Batten.—A scantling of stuff from two inches to seven inches in breadth, and from half an inch to one inch and a half in thickness.

* It has not been deemed necessary to include in this Chapter such Terms as have already been explained. General Terms used in Building are given in the Glossary and Index hereafter.

Baulk.—A piece of fir or deal, from four to ten inches square, being the trunk of a tree of that species of wood, generally brought to a square, for the use of building.

Bead.—A round moulding, commonly made upon the edge of a piece of stuff. Of beads there are two kinds; one flush with the surface, called a *quirk-bead*, and the other raised, called a *cock-bead.*

Beam.—A horizontal timber, used to resist a force or weight; as a *tie-beam*, where it acts as a string or chain, by its tension; as a *collar-beam*, where it acts by compression; as a *bressummer*, where it resists a transverse insisting weight.

Bearer.—Any thing used by way of support to another.

Bearing.—The distance in which a beam or rafter is suspended in the clear: thus, if a piece of timber rests upon two opposite walls, the span of the void is called the *bearing*, and not the whole length of the timber.

Bench.—A platform supported on four legs, and used for planing upon, &c.

Bevel.—One side is said to be *bevelled* with respect to another, when the angle formed by these two sides is greater or less than a right angle.

Bird's Mouth.—An interior angle, formed on the end of a piece of timber, so that it may rest firmly upon the exterior angle of another piece.

Blade.—Any part of a tool that is broad and thin; as the blade of an axe, of an adze, of a chisel, &c.: but the blade of a saw is generally called the plate.

Blockings.—Small pieces of wood, fitted in, or glued, or fixed, to the interior angle of two boards or other pieces, in order to give strength to the joint.

Board.—A substance of wood contained between two parallel planes; as when the baulk is divided into several pieces by the pit-saw, the pieces are called *boards*. The section of boards is sometimes, however, of a triangular, or rather trapezoidal form; that is, with one edge very thin; these are called *feather-edged boards.*

Bond-Timbers.—Horizontal pieces, built in stone or brick walls, for strengthening them, and securing the battening, lath, and plaster, &c.

Bottom Rail.—The lowest rail of a door.

Boxings of a Window.—The two cases, one on each side of a window, into which the shutters are folded.

Brace.—A piece of slanting timber, used in truss-partitions, or in framed roofs, in order to form a triangle, and thereby rendering the frame immovable; when a brace is used by way of support to a rafter, it is called a *strut*. Braces, in partitions and span-roofs, are always, or should be, disposed in pairs, and placed in opposite directions.

Brace and Bits.—The same as *stock and bits*, as explained hereafter.

Brad.—A small nail, having no head except on one edge. The intention is to drive it within the surface of the wood, by means of a hammer and punch, and to fill the cavity flush to the surface with putty.

Breaking Down, in sawing, is dividing the baulk into boards or planks; but, if planks are sawed longitudinally, through their thickness, the saw-way is called a *ripping-cut*, and the former a *breaking-cut*.

To Break-in.—To cut or break a hole in brick-work, with the ripping-chisel, for inserting timber, &c.

Breaking-Joint is the joint formed by the meeting of several heading joints in one continued line, which is sometimes the case in folded floors.

Bressummer or Breastsummer.—A beam supporting a superincumbent part of an exterior wall, and running longitudinally below that part.—See Summer.

Bridged Gutters.—Gutters made with boards, supported below with bearers, and covered over with lead.

Bridging Floors.—Floors in which *bridging-joists* are used.

Bridging-Joists.—The smallest beams in naked flooring, for supporting the boarding for walking upon.

Butting-Joint.—The junction formed by the surfaces of two pieces of wood, of which one surface is perpendicular to the fibres, and the other in their direction, or making with them an oblique angle.

Camber.—The convexity of a beam upon the upper edge, in order to prevent its becoming straight or concave by its own weight, or by the burden it may have to sustain, in course of time.

CAMBER-BEAMS.—Those beams used in the flats of truncated roofs, and raised in the middle with an obtuse angle, for discharging the rain-water towards both sides of the roof.

CANTALIVERS.—Horizontal rows of timber, projecting at right angles from the naked part of a wall, for sustaining the eaves or other mouldings. Sometimes they are planed on the horizontal and vertical sides, and sometimes the carpentry is rough and cased with joinery.

CARRIAGE of a STAIR.—The timber-work which supports the steps.

CARCASE of a BUILDING.—The naked walls, and the rough timber-work of the flooring and quarter partitions, before the building is plastered or the floors laid.

CARRY-UP.—A term used among builders or workmen, denoting that the walls, or other parts, are intended to be built to a certain given height; thus, the carpenter will say to the bricklayer, *Carry-up that wall; carry-up that stack of chimneys;* which means, build up that wall or stack of chimneys.

CASTING OR WARPING.—The bending of the surfaces of a piece of wood from their original position, either by the weight of the wood, or by an unequal exposure to the weather, or by unequal texture of the wood.

CHAMFERING.—Cutting the edge of any thing, originally right-angled, aslope or bevel.

CLAMP.—A piece of wood fixed to the end of a thin board, by mortise and tenon, or by groove and tongue; so that the fibres of the one piece, thus fixed, traverse those of the board, and by this mean prevent it from casting: the piece at the end is called a *clamp*, and the board is said to be *clamped*.

CLEAR STORY WINDOWS, are those that have no transom.

CROSS-GRAINED STUFF, is that which has its fibres running in contrary positions to the surfaces; and, consequently, cannot be made perfectly smooth, when planed in one direction, without turning it, or turning the plane.

CROWN-POST.—The middle post of a trussed roof.—See KING-POST.

CURLING STUFF.—That which is occasioned by the winding or coiling of the fibres round the boughs of the tree, when they begin to shoot from the trunk.

Deal Timber.—The timber of the fir-tree, as cut into boards, planks, &c., for the use of building.

Discharge.—A post trimmed up under a beam, or part of a building which is weak, or overcharged by weight.

Door-frame.—The surrounding case of a door, into which, and out of which, the door shuts and opens.

Dormer, or Dormer-Window.—A projecting window, in the roof of a house; the glass-frame, or casements, being set vertically, and not in the inclined sides of the roofs: thus *dormers* are distinguished from *skylights*, which have their sides inclined to the horizon.

Drag.—A door is said to *drag* when it rubs on the floor. This arises from the loosening of the hinges, or the settling of the building.

Dragon-Beam.—The piece of timber which supports the hip-rafter, and bisects the angle formed by the wall-plates.

Dragon-Piece.—A beam bisecting the wall-plate, for receiving the heel or foot of the hip-rafters.

Edging.—Reducing the edges of ribs or rafters, externally or internally, so as to range in a plane, or in any curved surface required.

Enter.—When the end of a tenon is put into a mortise, it is said to *enter* the mortise.

Face-mould.—A mould for drawing the proper figure of a hand-rail on both sides of the plank; so that, when cut by a saw, held at a required inclination, the two surfaces of the rail-piece, when laid in the right position, will be every where perpendicular to the plan.

Fang.—The narrow part of the iron of any instrument which passes into the stock.

Feather-edged Boards.—Boards, thicker at one edge than the other, and commonly used in the facing of wooden walls, and for the covering of inclined roofs, &c.

Fence of a Plane.—A guard, which obliges it to work to a certain horizontal breadth from the arris.

Filling-in Pieces.—Short timbers, less than the full length, as the jack-

rafters of a roof, the puncheons, or short quarters, in partitions, between braces and sills, or head-pieces.

Fine-set.—A plane is said to be fine-set, when the sole of the plane so projects as to take a very thin broad shaving.

Fir Poles.—Small trunks of fir-trees, from ten to sixteen feet in length, used in rustic buildings and out-houses.

Free Stuff.—That timber or stuff which is quite clean, or without knots, and works easily, without tearing.

Frowy Stuff.—The same as free stuff.

Furrings.—Slips of timber nailed to joists or rafters, in order to bring them to a level, and to range them into a straight surface, when the timbers are sagged, either by casting, or by a set which they have obtained by their weight, in length of time.

Girder.—The principal beam in a floor for supporting the binding-joists.

Glue.—A tenacious viscid matter, which is used as a cement, by carpenters, joiners, &c.

Glues are found to differ very much from each other, in their consistence, colour, taste, smell, and solubility. Some will dissolve in cold water, by agitation; while others are soluble only at the point of ebullition. The best glue is generally admitted to be transparent, and of a brown yellow colour, without either taste or smell. It is perfectly soluble in water, forming a viscous fluid, which, when dry, preserves its tenacity and transparency in every part; and has solidity, colour, and viscidity, in proportion to the age and strength of the animal from which it is produced. To distinguish good glue from bad, it is necessary to hold it between the eye and the light; and if it appears of a strong dark brown colour, and free from cloudy or black spots, it may be pronounced to be good. The best glue may likewise be known by immersing it in cold water for three or four days, and if it swells considerably without melting, and afterwards regains its former dimensions and properties by being dried, the article is of the best quality.

In preparing glue for use, it should be softened and swelled by steeping it in cold water for a number of hours. It should then be dissolved, by gently

boiling it till it is of a proper consistence to be easily brushed over any surface. A portion of water is added to glue, to make it of a proper consistency, which proportion may be taken at about a quart of water to half a pound of glue. In order to hinder the glue from being burned, during the process of boiling, the vessel containing the glue is generally suspended in another vessel, which is made of copper, and resembles in form a tea-kettle without a spout. This latter vessel contains only water, and alone receives the direct influence of the fire.

A little attention to the following circumstances will tend, in no small degree, to give glue its full effect in uniting perfectly two pieces of wood: first, that the glue be thoroughly melted, and used while boiling hot; secondly, that the wood be perfectly dry and warm; and, lastly, that the surfaces to be united should be covered only with a thin coat of glue, and after having been strongly pressed together, left in a moderately warm situation, till the glue is completely dry. When it so happens that the face of surfaces to be glued cannot be conveniently compressed together in any great degree, they should, as soon as besmeared with the glue, be rubbed lengthwise, one on the other, several times, in order thereby to settle them close. When all the above circumstances cannot be combined in the same operation, the hotness of the glue and the dryness of the wood should, at all events, be attended to.

The qualities of glue are often impaired by frequent meltings. This may be known to be the case when it becomes of a dark and almost black colour; its proper colour being a light ruddy brown: yet, even then, it may be restored, by boiling it over again, refining it, and adding a sufficient quantity of fresh; but the fresh is seldom put into the kettle till what is in it has been purged by a second boiling.

If common glue be melted with the smallest possible quantity of water, and well mixed by degrees with linseed oil, rendered dry by boiling it with litharge, a glue may be obtained that will not dissolve in water. By boiling common glue in skimmed milk the same effect may be produced.

A small portion of finely levigated chalk is sometimes added to the common solution of glue in water, to strengthen it and fit it for standing the weather.

A glue that will resist both fire and water may be prepared by mixing a handful of quick lime with four ounces of linseed oil, thoroughly levigated, and then boiled to a good thickness, and kept in the shade, on tin-plates, to dry. It may be rendered fit for use by boiling it over a fire like common glue.

Grind Stone.—A cylindrical stone, by which, on its being turned round its axis, edge-tools are sharpened, by applying the basil to the convex surface.

Ground-Plate or Sill.—The lowest plate of a wooden building for supporting the principal and other posts.

Grounds.—Pieces of wood concealed in a wall, to which the facings or finishings are attached, and having their surfaces flush with the plaster.

Handspike.—A lever for carrying a beam, or other body, the weight being placed in the middle, and supported at each end by a man.

Hanging Stile.—The stile of a door or shutter to which the hinge is fastened: also, a narrow stile fixed to the jamb on which a door or shutter is frequently hung.

Hip-Roof.—A roof, the ends of which rise immediately from the wall-plate, with the same inclination to the horizon, as its other two sides. The *Backing of a Hip* is the angle made on its upper edge to range with the two sides or planes of the roof between which it is placed.

Hoarding.—An inclosure of wood about a building, while erecting or repairing.

Jack Rafters.—All those short rafters which meet the hips.

Jack Ribs.—Those short ribs which meet the angle ribs, as in groins, domes, &c.

Jack Timber.—A timber shorter than the whole length of other pieces in the same range.

Intertie.—A horizontal piece of timber, framed between two posts, in order to tie them together.

Joggle-Piece.—A truss-post, with shoulders and sockets for abutting and fixing the lower ends of the struts.

Joists.—Those beams in a floor which support, or are necessary in the supporting, of the boarding or ceiling; as the *binding, bridging,* and *ceiling, joists:* girders are, however, to be excepted, as not being joists.

Juffers.—Stuff of about four or five inches square, and of several lengths. This term is out of use, though frequently found in old books.

Kerf.—The way which a saw makes in dividing a piece of wood into two parts.

King-Post.—The middle post of a trussed roof, for supporting the tie-beam at the middle, and the lower ends of the struts.

Knee.—A piece of timber cut at an angle, or having grooves to an angle. In hand-railing a *knee* is a part of the back, with a convex curvature, and therefore the reverse of a *ramp,* which is hollow on the back.

Knot.—That part of a piece of timber where a branch had issued out of the trunk.

Lining of a Wall.—A timber boarding, of which the edges are either rebated or grooved and tongued.

Lintels.—Short beams over the heads of doors and windows, for supporting the inside of an exterior wall; and the super-incumbent part over doors, in brick or stone partitions.

Lower Rail.—The rail at the foot of a door next to the floor.

Lying Panel.—A panel with the fibres of the wood disposed horizontally.

Margins or Margents.—The flat part of the stiles and rails of framed work.

Middle Rail.—The rail of a door which is upon a level with the hand when hanging freely and bending the joint of the wrist. The back of the door is generally fixed in this rail.

Mitre.—If two pieces of wood be formed to equal angles, or if the two sides of each piece form equal inclinations, and two sides, one of each piece, be joined together at their common vertex, so as to make an angle, or an inclination, double to that of either piece, they are said to be *mitred* together, and the joint is called the *mitre.*

MORTISE and TENON.—These terms have been defined on pages 159, 160: but, as no rules have ever yet been laid down, as a guide to the workman in choosing the proportions that mortises and tenons ought to bear to the wood, and as he is, therefore, left to depend entirely upon practice, we shall here notice that, from observing the proportions which are generally used and found to answer best, it is no difficult task to lay down a few regulations, as *data*, to which the workman may satisfactorily refer in his practice.

The TENON, in general, may be taken at about one-third of the thickness of the stuff.

When the mortise and tenon are to lie horizontally, as the juncture will thus be unsupported, the tenon should not be more than one-fifth of the thickness of the stuff; in order that the strain on the upper surface of the tenoned piece may not split off the under cheek of the mortise.

When the piece that is tenoned is not to pass the end of the mortised piece, the tenon should be reduced one-third or one-fourth of its breadth, to prevent the necessity of opening one side of the tenon. As there is always some danger of splitting the end of the piece in which the mortise is made, the end beyond the mortise should, as often as possible, be made considerably longer than it is intended to remain; so that the tenon may be driven tightly in, and the superfluous wood cut off afterwards.

But the above regulations may be varied, according as the tenoned or mortised piece is weaker or stronger.

The labour of making deep mortises, in hard wood, may be lessened, by first boring a number of holes with the auger, in the part to be mortised, as the compartments between may then more easily be cut away by the chisel.

Before employing the saw to cut the shoulder of a tenon, in neat work, if the line of its entrance be correctly determined by nicking the place with a paring chisel, there will be no danger of the wood being torn at the edges by the saw.

As the neatness and durability of a juncture depend entirely on the sides of the mortise coming exactly in contact with the sides of the tenon; and, as this is not easily performed when a mortise is to pass entirely through a

piece of stuff, the space allotted for it should be first of all correctly gauged on both sides. One-half is then to be cut from one side, and the other half from the opposite side; and as any irregularities which may arise from an error in the direction of the chisel, will thus be confined to the middle of the mortise, they will be of very little hinderance to the exact fitting of the sides of the mortise and tenon. Moreover, as the tenon is expanded by wedges after it is driven in, the sides of the mortise may, in a small degree, be inclined towards each other, near the shoulders of the tenon.

Mullion or Munnion.—A large vertical bar of a window-frame, separating two casements, or glass-frames, from each other.

Vertical *mullions* are called *munnions;* and those which extend horizontally are *transoms.*

Muntins or Montants.—The vertical pieces of the frame of a door between the stiles.

Naked Flooring.—The timber-work of a floor for supporting the boarding, or ceiling, or both.

Newel.—The post, in dog-legged stairs, where the winders terminate, and to which the adjacent string-boards are fixed.

Ogee.—A moulding, the transverse section of which consists of two curves of contrary flexure.

Panel.—A thin board, having all its edges inserted in the groove of a surrounding frame.

Pitch of a Roof.—The inclination which the sloping sides make with the plane, or level of the wall-plate; or it is the proportion which arises by dividing the span by the height. Thus, if it be asked, What is the pitch of such a roof? the answer is, one-quarter, one-third, or half. When the pitch is half, the roof is a square, which is the highest that is now in use, or that is necessary in practice.

Plank.—All boards above nine inches wide are called *planks.*

Plate.—A horizontal piece of timber in a wall, generally flush with the inside, for resting the ends of beams, joists, or rafters, upon; and, therefore, denominated floor or roof plates.

Posts.—All upright or vertical pieces of timber whatever; as *truss-posts, door-posts, quarters* in partitions, &c.

Prick Posts.—Intermediate posts in a wooden building, framed between principal posts.

Principal Posts.—The corner posts of a wooden building.

Pudlaies.—Pieces of timber to serve the purpose of handspikes.

Punchions.—Any short post of timber. The small quarterings in a stud partition, above the head of a door, are also called *punchions.*

Purlins.—The horizontal timbers in the sides of a roof, for supporting the spars or small rafters.

Quartering.—The stud work of a partition.

Quarters.—The timbers to be used in stud partitions, bond in walls, &c.

Rafters.—All the inclined timbers in the sides of a roof; as *principal rafters, hip rafters,* and *common rafters;* the latter are called, in most countries, *spars.*

Rails.—The horizontal pieces which contain the tenons in a piece of framing, in which the upper and lower edges of the panels are inserted.

Raising Plates, or Top Plates.—The plates on which the roof is raised.

Rank-set.—The edge of the iron of a plane is said to be *rank-set* when it projects considerably below the sole.

Return.—In any body with two surfaces, joining each other at an angle, one of the surfaces is said to *return* in respect of the other; or, if standing before one surface, so that the eye may be in a straight line with the other, or nearly so: this last is said to *return.*

Ridge.—The meeting of the rafters on the vertical angle, or highest part, of a roof.

Risers.—The vertical sides of the steps of stairs.

Roof.—The covering of a house; but the word is used in carpentry for the wood-work which supports the slating, or other covering.

Scantling.—The transverse dimensions of a piece of timber; sometimes, also, the small timbers in roofing and flooring are called *scantlings.*

Scarfing.—A mode of joining two pieces of timber, by bolting or nailing

them transversely together, so that the two appear but as one. The joint is called a *scarf*, and the timbers are said to be *scarfed.*

Shaken Stuff.—Such timber as is rent or split by the heat of the sun, or by the fall of the tree, is said to be *shaken.*

Shingles.—Thin pieces of wood used for covering, instead of tiles, &c.

Shreadings.—A term not much used at present.—See Furrings, page 223.

Skirtings or Skirting Boards.—The narrow boards round the margin of a floor, forming a plinth for the base of the *dado,* or simply a plinth for the room itself, when there is no dado.

Skirts of a Roof.—The projecture of the eaves.

Sleepers.—Pieces of timber for resting the ground-joists of a floor upon, or for fixing the planking to, in a bad foundation. The term was formerly applied to the *valley-rafters* of a roof.

Spars.—A term by which the common rafters of a roof are best known in almost every provincial town in Great Britain; though, generally, called in London *common rafters,* in order to distinguish them from the principal rafters.

Staff.—A piece of wood fixed to the external angle of the two upright sides of a wall, for floating the plaster to, and for defending the angle against accidents.

Stiles of a Door, are the vertical parts of the framing at the edges of the door.

Struts.—Pieces of timber which support the rafters, and which are supported by the truss-posts.

Summer.—A large beam in a building, either disposed in an outside wall, or in the middle of an apartment, parallel to such wall. When a *summer* is placed under a superincumbent part of an outside wall, it is called a *bressummer,* as it comes in abreast with the front of the building.

Surbase.—The upper base of a room, or rather the cornice of the pedestal of the room, which serves to finish the dado, and to secure the plaster against accidents from the backs of chairs, and other furniture on the same level.

Taper.—The form of a piece of wood which arises from one end of a piece being narrower than the other.

TENON.—See MORTISE.

TIE.—A piece of timber, placed in any position, and acting as a string or tie, to keep two things together which have a tendency to a more remote distance from each other.

TRANSOM WINDOWS.—Those windows which have horizontal mullions.

TRIMMERS.—Joists into which other joists are framed.

TRIMMING JOISTS.—The two joists into which a trimmer is framed.

TRUNCATED ROOF.—A roof with a flat on the top.

TRUSS.—A frame constructed of several pieces of timber, and divided into two or more triangles by oblique pieces, in order to prevent the possibility of its revolving round any of the angles of the frame.

TRUSSED ROOF.—A roof so constructed within the exterior triangular frame, as to support the principal rafters and the tie-beam at certain given points.

TRUSS-POST.—Any of the posts of a trussed roof, as a *king-post, queen-post,* or *side-post,* or posts into which the braces are formed in a trussed partition.

TRUSSELS.—Four-legged stools for ripping and cross-cutting timber upon.

TUSK.—The bevelled upper shoulder of a tenon, made in order to give strength to the tenon.

VALLEY RAFTER.—That rafter which is disposed in the internal angle of a roof.

UPHERS.—Fir-poles, from twenty to forty feet long, and from four to seven inches in diameter, commonly hewn on the sides, so as not to reduce the wane entirely. When slit they are frequently employed in slight roofs; but mostly used whole for scaffolding and ladders.

WALL-PLATES.—The joist-plates and raising plates.

WEB of an IRON.—The broad part of it which comes to the sole of the plane.

## 2.—TOOLS USED IN CARPENTRY AND JOINERY.

CARPENTER'S TOOLS.—The principal tools used in the rougher operations of Carpentry are the *Axe*, the *Adze*, the *Chisel*, the *Saw*, the *Mortise* and *Tenon Gauge*, the *Square*, the *Plumb-rule*, the *Level*, the *Auger*, the *Crow*, and the *Draw-bore Pin*, or *Hook-pin*, for drawboring. Of these the figures are represented in *plate* LXVII, saws excepted, which are shown in *plate* LXVIII, and described hereafter. These tools are all too well known to require a copious description.

The AXE, *fig.* 1, (*pl.* LXVII,) is an edged tool, with a long wooden handle, used for chopping or trimming timber to a given form, and to prepare surfaces for being smoothed with the adze.

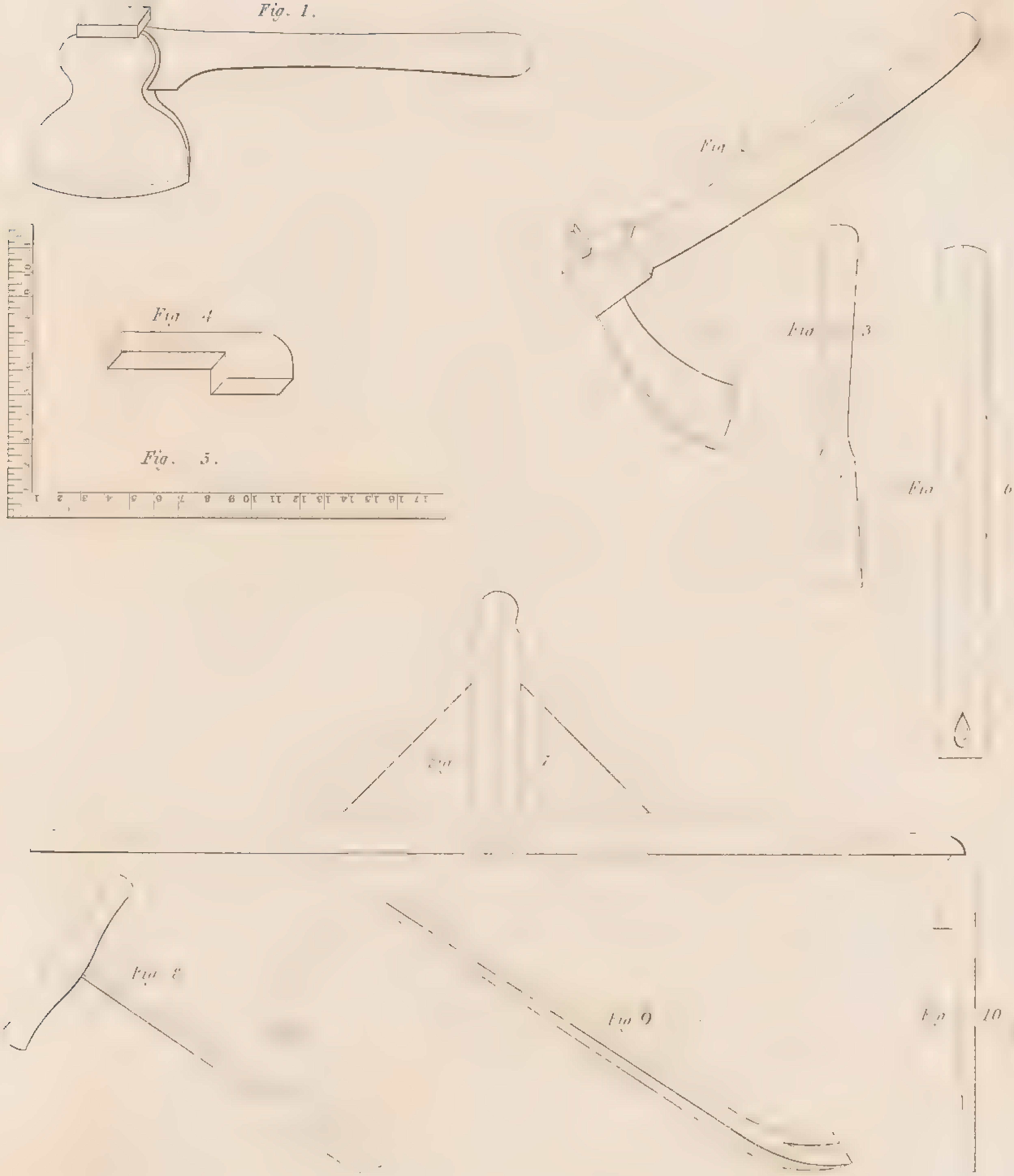
The ADZE, *fig.* 2, a sharp-edged tool, used for the purpose of trimming surfaces smooth, by chopping, in a horizontal position, after the operation of the saw or axe.

The CHISEL.- The *Socket-Chisel*, used in mortising, (*fig.* 3,) differs from other chisels, (described hereafter,) in having a conical socket to receive the handle, instead of a tang and shoulder. It is commonly an inch and a quarter or an inch and a half broad. The lower part is a prismoid, the sides of which taper considerably downward, and the edges upward. The under end is in the form of a wedge, with the basil on the iron side and the edge on the lower end of the steel face.

MORTISE and TENON GAUGE.—See GAUGE, hereafter.

The SQUARE (*pl.* LXVII, *fig.* 5).—The *Carpenter's Square* is a rule of iron, about an inch broad, forming a right-angled triangle, and graduated into inches and parts. Of its two legs, one is eighteen and the other twelve inches in length. The first is numbered from the exterior angle ; and the tops of the figures are, therefore, toward the outer edge. The other leg is numbered from the extremity towards the angle, and its figures are read from

# CARPENTERS TOOLS.




Engraved by W. Sims

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the internal angle, as in the other side. This instrument is equally useful as a Square, a Level, and a Rule. Its use as a level, in taking angles, has been shown, thus: To take the angle which the heel of a rafter makes with the back, apply the end of the short leg to the heel-point of the rafter, and the edge of the square level across the plate; extend a line from the ridge to the heel-point, and where this line cuts the perpendicular line of the square, mark the inches, and this will show how much it deviates from the square.

The Plumb-rule (*pl.* LXVII, *fig.* 6).—An oblong or prismatic piece of wood, having a line drawn down the middle of one side, parallel to the arrises or edges of the same face. It is used for ascertaining the vertical position of posts, &c., and so as to set them perpendicular to the horizon, by means of a plummet, or plumb, suspended by a line from the upper end of the rule, and allowed to vibrate freely, by an aperture in the lower end of the same.

To set up a post perpendicular, place the bottom of it in the situation required, and the sides as nearly vertical as the eye can direct. If insulated, let it thus be fixed with temporary braces, at least from two adjoining sides, but, if very heavy, from all the four sides: then try the plumb-rule upon one side, and if the thread coincides with the line, that side of the post is already *plumb,* or upright; but if not, the top of the post must be moved forward or backward, as it may lean or hang, so much as required, until it is erect; and this is to be effected by previously moving the front and rear braces and fixing them anew, while the others remain to support the other sides. Again, applying the rule as before, if there be a coincidence between the line and plummet-thread, the face is perpendicular; but, if not, similar operations must be repeated, until it is found to be so. Proceed thus with the other two sides of the post, until these also are *plumb,* and the true vertical position will be determined.

The Level (*pl.* LXVII, *fig.* 7).—A long rule of wood, ten or twelve feet in length, straight on one edge, and having another piece, in the middle of its length, fixed perpendicular thereto, with its sides in the same plane as the sides of the rule. The vertical piece is generally mortised into the other,

and firmly braced on each side, so as to secure it firmly in its position. This piece has its upper end kerfed in three places; one through the perpendicular line, and one on each side. On the under side of the straight edge of the transverse is a hole or notch, cut equally on each side of the perpendicular line. A plummet is so suspended by a string, from the middle kerf at the top of the vertical or standing piece, that, when hanging at length, the bottom of the plummet may not reach to the straight edge, but vibrate freely in the hole or notch.

If the straight edge of the level be applied to two distant points, the two sides being placed vertically, while the plummet hangs freely, and coincides with the straight line on the vertical piece, then these points are level: if otherwise, imagine one to be at the given height; then the other is to be heightened or lowered so as to make it level; and thus the implement is to be applied until the thread coincides with the perpendicular line.

In carpentry, the level is used to lay the upper edges of joists in naked flooring horizontal, by first levelling two beams as remote from each other as the length of the level will allow: the plummet may then be taken off, and the level used as a straight edge. In *levelling joists*, the best method is, first to make two remote joists level in themselves; that is to say, each throughout its own length, then the two level with each other: having settled these, bring one end of the intermediate joists straight with the two which have been levelled, then the other ends in the same manner; next apply the straight edge longitudinally on each intermediate joist, when those found to be hollow, if any, must be furred up.

*The Level is adjusted* by placing it in its vertical situation upon two pins or blocks of wood; then, if the plummet hangs freely, and settles upon the line in the standing piece, it is correct; but, if not, raise one end or lower the other to make it do so; then turn the level end for end, and if the plummet falls upon the line the level is just; if not, the bottom edge must be shot straight, and as much taken off as may be requisite, which will be ascertained by trying the level first one way and then the other, as before, until a perfect coincidence between the thread and the line is obtained.

The Auger (*pl.* LXVII, *fig.* 8).—*The Auger* is the largest of all tools which are used for boring wood. It has a shaft, with a wooden handle at the upper end, at right angles with the shaft, which is towards the lower end made of steel, and the other portion of iron. The steel part is of a prismoidal form to some distance from the end, upwards. The point, or lower end, being furnished with a worm or screw, of a conic form, for the more readily entering the wood. The edges are almost parallel, though the sides taper, in a small degree, upwards. The upper portion of the shaft, above the steel part, is generally of a less size than the lower part, in order that it may pass the bore more freely. The axis of the shaft and the axis of the worm are in the same straight line. The lower end is, on one side of the cone, cut into a cavity, and forms on the narrow surface of the prism a projecting cutting edge, called the *tooth*. The lower end of the other side of the cone projects in the form of a wedge before the prismoidal part of the face, the cutting edge being formed by the line of concourse of the two sides of the wedge. The greatest extremity of the lower end is the vertex of the cone, the cutting edge of the tooth being somewhat nearer to the handle, and the cutting edge of the wedge-like part nearer still.

This construction of the auger is of very modern date; but it has many advantages over the older form, as, without any previous hole, it pierces the wood much truer; and, likewise, it spontaneously discharges the chips or core in the form of a spiral shaving; neither of which properties the older form of the auger possesses.

The Crow (*pl.* LXVII, *fig.* 9).—A large bar of iron, used as a lever to raise the ends of heavy timber, in order to lay a roller or another piece of timber under it. This instrument is commonly formed with claws, as represented in the plate.

The Draw-bore Pin (*pl.* LXVII, *fig.* 10).—A conical implement of iron, with a hooked head, declining upwards in the form of a wedge. They are furnished with tangs and shoulders, and fitted into handles like chisels. They are used after the tenons have been entered in the mortises, and bored, to draw the shoulders of the tenons home to their abutments in the mortise-

cheeks, in the following manner: the tenon is inserted, and drawn as nearly into its proper place as possible, and then marked on both sides, through the hole in the mortise-cheeks. The tenon is then taken out again, and bored through a little nearer the shoulder than the centre of these marks, and again entered, and brought with its shoulder as near to the abutment as possible. By thus using the draw-bore pins, the wood on the sides of the holes will be hardened; and thus the wooden peg, when driven in, will maintain a firmer hold.

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## OTHER TOOLS, USED INDISCRIMINATELY BY CARPENTERS AND JOINERS, ARE AS FOLLOW:

Beetle or Maul.—A larger kind of mallet, (see *Mallet*, hereafter,) having a handle about three feet long, and used for knocking the corners of framed work, to set it in its proper position, and for driving short piles into the ground, for which purposes both hands are employed in striking the blow.

Bench (*pl.* LXIX, *fig.* 12).—The *Joiner's Bench* is composed of a platform or *top*, supported by four substantial legs. Near the fore-end is an upright prismatic pin, *a*, which slides stiffly in a mortise through the top. This is called the *Bench-hook*, and ought to be fitted so tight as to be moved up and down by the blow of a hammer or mallet only. The use of the bench-hook is to keep the wood steady, while the workman, in the act of planing, presses it forward. ABCD is a vertical board, called the *side-board*, fixed to the legs, on the hither side of the bench, and flush with the legs. At the farther end of the side-board, opposite to it and the bench-hook, is a rectangular prismatic piece of wood, *b b*, the two broad surfaces of which are parallel to the vertical face of the side-board: this is moveable, in a straight horizontal direction, by mean of a screw, passing through an interior screw, fixed to the inside of the side-board, and called the *screw-check*. The screw and screw-check together are called the *bench-screw;* and the two adjacent vertical surfaces of the screw-check and of the side-board have been denominated the *cheeks* of the bench-screw.

The bench-screw is used to fasten boards between the cheeks, in order to plane their edges; but as the screw holds up only one end of a board, the leg E of the bench, and the side-board, are both pierced with holes, each of which admits a pin for supporting the other end at any required height. The screw-check has also a horizontal piece, called the *Guide*, which is mortised and fixed fast to it, and made to slide through the side-board, for preventing its turning round.

The heights of benches vary; but the medium is about two feet eight inches. The common length is from ten to twelve feet; and breadth two feet six inches. The top-boards upon the farther side are sometimes only ten feet long, while the front side is twelve feet: thus projecting two feet at the hinder part, or end to the right hand.

In order to prevent tottering, the legs of the bench should not be less than three inches and a half square; and they should be well braced, particularly the two on the working side. The top-board, in front, should be from one inch and a half to two inches thick; the thicker the better. The boards on the farther side may be from an inch to an inch and a quarter thick.

Each pair of end legs are mostly coupled together by two rails dovetailed into them. Between each pair of coupled legs the length of the bench is commonly divided into three or four equal parts, and transverse bearers fixed at the divisions to the side-boards, the upper sides being flush with those of the side-boards, for the purpose of supporting the top firmly, and keeping it from bending. The place of the screw is behind the two fore legs; that of the bench-hook immediately before the bearers of the fore legs; and that of the guide at some distance before the bench-hook.

For the convenience of keeping things out of the way, the rails at the ends are boarded; and, for farther accommodation, some benches have a *locker*, or cavity, which is formed by boarding the under edges of the side-boards before the hind legs, and closing the ends vertically, so that this cavity is between the top and the boarding under the side-boards: the opening to

it is an aperture formed by sliding a part of the top-board towards the hinder end.

The bench-hook is sometimes covered with an iron plate, the front edge of which is formed into sharp teeth, which stick fast into the wood to be planed, so as to prevent its slipping. Instead of such a plate, nails may be driven obliquely through the edge, and filed into points, having a wedge-like form.

The Bevel, (*pl.* LXVIII, *fig.* 12,) is similar to the *Square,* described hereafter, and having a *stock, ab;* and *blade, bc.* As the blade of this implement is moveable, it may readily be applied to the angle of any piece of stuff, so as to transfer it to another piece; but the joint must be very stiff, or it cannot be depended on for remaining in the same position in which it was set. The joiner's bevel, though not usually so made, would be much superior to what it is at present, if made in the same manner as the bevel used by the stone-mason; that is to say, with a screw adapted to it, so as to fix and retain the blade at any angle which may be required.

Bits.—See *Stock and Bits,* hereafter.

Brad-awl, or Sprig-bit, (*pl.* LXVIII, *fig.* 3,) is the smallest tool used for boring; it is formed for making perforations to admit the small slender nails, without heads, called *brads* or *sprigs.* The handle is the frustum of a cone, tapering downwards, and is fastened into the brad-awl as far as the shoulder, which commences where the tang terminates. The steel part, below the shoulder, is cylindrical nearly to the extremity, which is flattened, and forms the cutting edge by the meeting of two basils, ground equally from each side. The hole formed by the brad-awl is made by placing the cutting edge transversely to the fibres of the wood, and working it to and fro about half round before the motion is reversed. The hole made by the brad-awl is not produced as by other boring tools, which take away a part of the substance of the wood, but by displacing and condensing it around the hole.

Chisels. (*pl.* LXVIII, *fig.* 4, &c.)—The very large kinds of chisels, which are used for heavy and coarse work, are generally made of steel and iron,

# JOINERS TOOLS.


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Engraved by W. Lymans

welded together. But the far greater portion is of iron, as the steel seldom, if ever, extends higher that the broad part of the chisel, and is often no thicker than a third part of the whole mass of metal. The middle-sized and smaller kinds of chisels are always made of cast steel.

As all chisels, except those used in turning, and the socket-chisel, are more or less worked by being driven with the percussive force of a hammer or mallet, they are formed with a shoulder, to abut against the end of the handle, into which the *tang* is driven, in order to prevent the handle from being split by the force of the blows. The *basil* of chisels is on one side, and, when well formed, is perfectly flat.

We shall now enumerate the chisels which are most generally used. The handles of chisels which are to be driven by concussion should be made convex, as they will then be less liable to be split, or injured by blows.

The Gouge of the carpenter and cabinet-maker is similar in size and form to that used by the turner, but it is not always set in the same manner; the edge of the turner's being convex, whereas that of the joiner and cabinet-maker is, for small work, made straight across the end. But as the mill-wrights generally cut with the gouge perpendicularly, the gouge used by them often has the basil on the hollow or concave side of the gouge.

For the Socket-Chisel, see *Carpenter's Tools,* page 232. It is the same in carpentry as the mortise-chisel is in joinery.

The Firmer Chisel, (*pl.* LXVIII, *fig.* 4,) is a thin broad chisel, with the sides parallel to a certain length, and then tapering, so as to become much narrower towards the shoulder. It is used by being driven by the blows of a mallet on the handle.

The Paring Chisel differs from the above in no other respect than the manner of using it; being employed by the hand for cutting or paring, instead of being driven by a mallet.

The Mortise-Chisel, (*pl.* LXVIII, *fig.* 5,) as its name implies, is used in forming mortises. The section of this chisel is a rectangle, almost approaching to a square, with its basil on one side of its narrow sides. It is necessarily made very strong, as it would not otherwise be able to sustain the heavy

blows of the mallet, and still less the force that is often applied to it when it is used as a lever, to remove the pieces of wood which it cuts in the course of mortising.

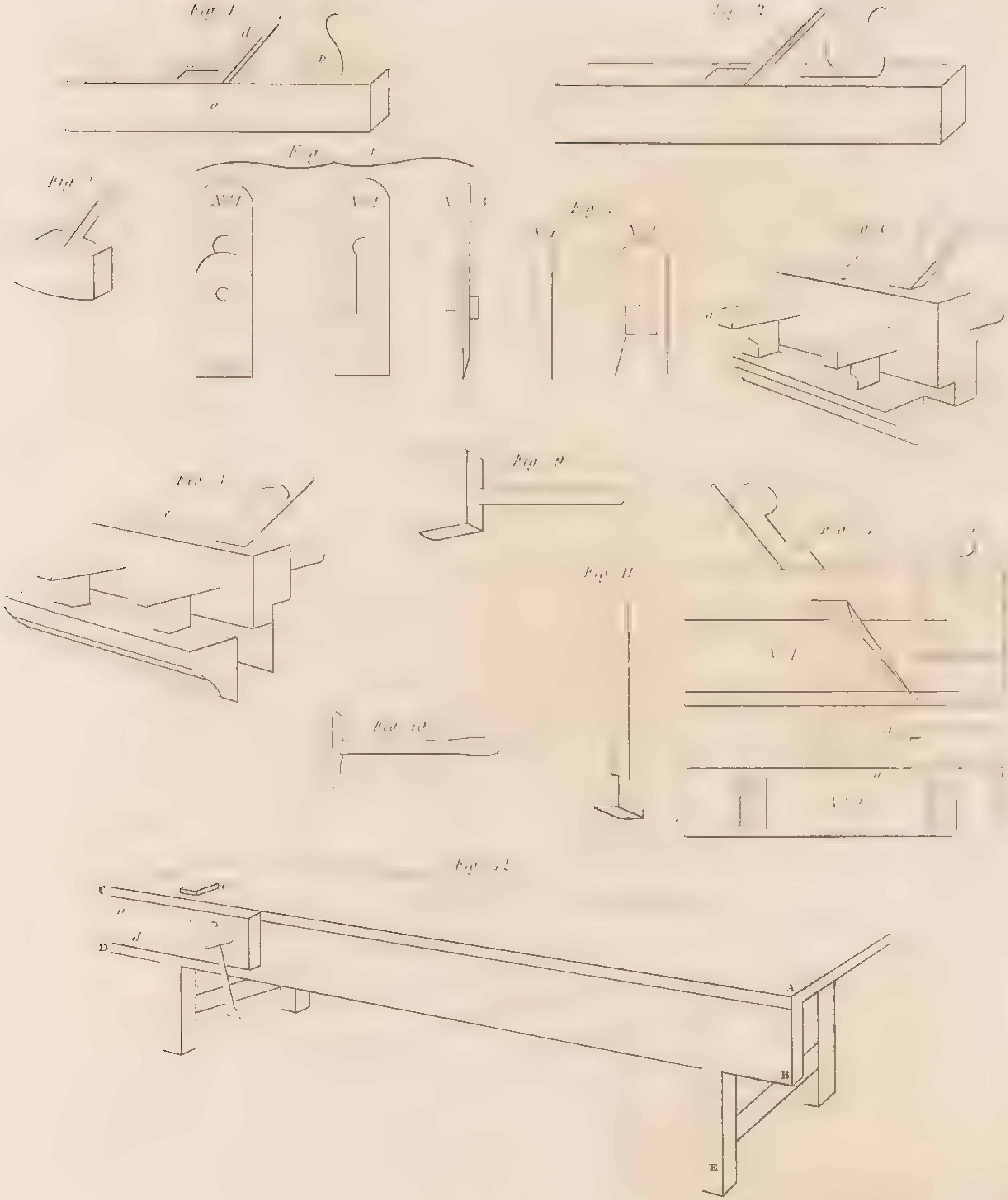
The Gauge (*pl.* LXVIII, *fig.* 13,) consists of a rectangular prism, called the *head*, with a mortise of the same figure cut through it, between two of its opposite sides. In the mortise is inserted another square prism, called the *stem*, which is furnished with a steel point, nearly at the end of one of the surfaces, in the direction of its length, and projecting just sufficient to mark the surface of a piece of stuff when pressed thereon. The head can be set at any required distance from the steel point, by striking one or other end of the stem with a mallet, and then securing it at the point desired, by means of a small wedge, which passes through one of the sides of the mortise, and bears upon the stem.

The *Mortise-Gauge* is similar to the common guage, only it is furnished with two teeth instead of one; the one of which can be placed at any distance from the other, which is stationary at the end of the stem. This guage, as its name implies, is used for gauging mortises and tenons.

The Gimblet (*pl.* LXVIII, *fig.* 2,) is a piece of steel, of a cylindric form, furnished with a worm or screw at the lower end, and with a transverse handle at the upper. It is used for boring small holes, by being turned round by the handle, while the screw at the other end draws it forward into the wood. To receive the core of the wood, it is formed with a cylindric cavity called the *cup*, just above the screw or worm; and it is by the edges, formed by means of the angle of the exterior and interior cylinders, that the fibres of the wood are cut across.

As the gimblet is a small tool of very slender construction, it is very liable to be twisted and broken before the workman is aware, unless it be frequently withdrawn, in order to remove the core excavated from the wood, as often as the cup or groove is filled. If the point of a gimblet is once broken, or the arris of the screw blunted, as it is very tedious and laborious to work with them in that state, they are generally thrown aside; but, though the grindstone cannot be applied for sharpening the gimblet, yet the point and

# JOINERS TOOLS.



arris of the screw may, in a few minutes, be rendered fit for use again, by being sharpened with a file.

Gouge.—See *Chisels*.

The Hammer (*pl.* LXIX, *fig.* 10,) consists of a piece of iron or steel, flat at one end, for driving nails, &c.; and furnished at the other end with claws, inclined backwards towards the handle, so that the other end of the hammer may not penetrate into the wood in the act of drawing out nails with the claws. This inclination, likewise, encreases the power employed, by lessening the distance of the force to be overcome by the fulcrum.

The heads of hammers are fastened into their handles by two different methods: the first, by having plates of iron, extending from the head on each side, and thus forming a socket for the reception of the handle, which is fastened therein by means of screws, admitted into the wood of the handle through one or more holes in each of these plates of iron; the second method of fastening the handle into the head, is by passing the handle through a perforation in the head, and fastening it therein by wooden wedges driven in at the end of it.

The object of having the head of the hammer perfectly well secured to the handle is indispensible, in order to avoid many accidents which might otherwise occur; but, though the first method is certainly well adapted to this end, yet, as the plates of iron render the handle inflexible at the very part where it is desirable that there should be some degree of spring, and, as the latter method possesses this advantage over the former, and may, moreover, be made equally secure, by dipping the wedges in glue before they are driven in; the latter manner of fastening the handle to the head must certainly obtain the preference.

The Mallet (*pl.* LXIX, *fig.* 9,) is, in construction, similar to the hammer, excepting that the head is a thick block of wood, in the form of the frustum of a pyramid. It possesses several advantages over the hammer; as, being of wood, it is less liable to damage substances struck with it; and being of equal weight, and, at the same time presenting a large surface, it is more easy to hit the ends of chisels, &c., with the mallet than with the hammer.

Mallets are generally made of the soundest and toughest wood that can be procured, as ash, beech, or the harder kinds of elm. They are usually made rather concave on that side into which the handle enters, and somewhat convex on the other; and, consequently, the ends with which the object is struck are not parallel with the handle, but inclined to it and to each other: but still the manner in which the blow is struck with the mallet, renders the striking end parallel with the surface struck.

Mallets are used principally for mortising and driving pins into wood.

MAUL.—See *Beetle*, page 236.

The MITRE SQUARE, an instrument so called because it bisects a right angle, or mitres a square; it is similar to the bevel, already described, excepting that the blade is set immoveably in the stock. It is used to strike an angle of forty-five degrees; this angle being required in joinery more frequently than any other angle, excepting the right angle.

The mitre square is used by laying the guide of the handle upon the arris, and sliding it along the face of the stuff till the oblique edge comes to the place required. By this edge the line required may be drawn.

PLANES.—Before we enter on a description of the various kinds of *Planes*, it may be useful to give a short explanation of the technical terms which it will be necessary to make use of in noticing this important class of tools. The *stock* (*a*, *fig.* 1, *pl.* LXIX,) is the block of wood in which the blade of the plane is fixed: it is generally made of well-seasoned beech, or any other species of close-grained hard wood. The *blade*, (*c*,) which is called the iron of the plane, is made of iron and steel, welded together; the lower portion of the fore part, which goes into the stock, being of steel, and the remaining part of iron.

The *sole* of a plane is the under side of the stock, and the *height* or *depth* is the dimension of the plane from the sole to the upper surface. The *bed*, (*e*,) which is a plane of various angles, according to the use for which the plane is intended, is the aperture in the stock, upon which the iron is laid, and secured by the wedge (*d*). The angle of the bed of the *jack-plane*, *trying-plane*, and *smoothing-plane*, is generally from forty-two to forty-five

degrees; that of the *moulding-plane* about forty-five; and of those planes which operate by scraping, not more than four or five degrees: that is, they are nearly perpendicular. The *pitch* is the angle which the iron makes with the perpendicular mentioned above; and the greater this angle, the lower is the pitch of the iron said to be. The *basil,* which is the sloping edge of the iron of the plane, forms an acute angle with that steel side which is not ground, but always kept level. In grinding and whetting the irons of planes the basil must be made as flat as possible, or rather, in a small degree, concave, otherwise it will not seem to be sharp when used. For working soft wood the basil is usually made in an angle of twelve degrees, and for hard wood eighteen; it being remarked that the more acute the basil is, the better the instrument cuts; and the more obtuse, the stronger and fitter it is for service. The handle of a plane (*b*) is called the *tote.*

The generality of planes are about three inches and one-eighth deep; the jack-plane being something more, and the smoothing-plane something less. As it was found remarkably difficult to plane cross-grained stuff with the planes in common use, it became necessary to make planes for this purpose with a double blade (Nos. 1, 2, 3, *fig.* 4). The addition, in this case, consists of a piece of iron of the same breadth as the blade, with its lower end very thin, and its edge of the same shape as the edge of the blade. This piece of iron is called the *top-iron,* and is fastened to the other blade, by means of a screw fixed in the under blade, at the most convenient and useful distance from the edge. The edge of the top-iron should never extend below the sole of the plane, and should be at a certain distance from the edge of the plane, according to the thickness of the shaving which is required to be taken. The edge of the top-iron is arched in a small degree towards the lower end, so that the screw may necessarily make it fit so correctly to the level surface of the blade, that no shavings can get between, which is indispensible for its working clean and neat. The top-iron is generally used in the jack-plane, trying-plane, long-plane, and jointer-plane; but not in the smoothing-plane, or in any of the various kinds of moulding planes.

The *Wedge,* for tightening the iron, is represented in Nos. 1 and 2, *fig.* 5. The first being the longitudinal section, and the second the front, with the hollow below for the head of the screw.

If, after having fastened the wedge of a plane, it is found that the iron projects too much, the blow of a hammer on the fore-end of the stock, or on the upper surface, near the orifice for the shavings, will slacken the wedge, so that it may easily be withdrawn by the hand, and fastened again more correctly.

We shall now give a short account of the various kinds of planes, and their general uses.

The *Jack-Plane* (*pl.* LXIX, *fig.* 1,) is the first which is used by the joiner, being about seventeen inches in length, and adapted for taking off the greater irregularities, which any other instrument may have left on the surface of the stuff. The cutting edge of the iron of this plane rises with an arch of considerable convexity, in order to suit the coarseness of the work: for the same end, the mouth or opening for admitting the shavings through the stock is much wider at the sole than that of any other plane. The convexity of the cutting edge of the iron is necessary, in order that the work may not be spoiled, nor the progress of the workman impeded, by the corners of the blade of the plane entering the wood. The iron is often used without a cover: and its projection must depend on the nature and convexity of the stuff to be worked. If it be very hard and knotty, the projection must be much less than if it were for the most part of a clean unbroken nature. Experience will soon teach the proper degree requisite, as the workman will soon discover when it takes hold so deeply as to tear the stuff and produce additional labour, or when it requires more than usual pressing down, or a repetition of the strokes, in order to reduce the wood. Both these extremes must be avoided. This plane is worked only within the arms' length.

The *Trying-Plane,* (*pl.* LXIX, *fig.* 2,) having a *double tote,* is used to regulate and smooth, to a higher degree, the surface of a piece of stuff that has already been reduced to its intended form by means of the jack-plane.

Its length is about twenty-one or twenty-two inches. The iron does not project so much as that of the jack-plane, and it is likewise broader and less convex on its edge. It is worked by pushing it along the whole length of the stuff, and thus taking off a shaving of the same length.

The *Long Plane* is the third plane made use of in facing a piece of stuff, which it does with the utmost exactness. It is generally about two feet three or four inches in length, with a somewhat broader iron than the trying-plane, and with less projection and convexity.

The *Jointer-Plane* is the longest of all the planes; its edge is very fine, with barely the projection of a hair's breadth. Its length is about thirty inches; and it is used for shooting the edges to boards perfectly straight, so that their juncture may scarcely be discernible when their surfaces are joined together.

The *Strike-Block Plane* is similar in nature to the jointer, but much smaller, being only about eleven or twelve inches in length. It is used in the place of the jointer for shooting short blocks, or the ends of boards across the fibres, when the great dimensions of the jointer would render it very unhandy for these purposes. The angle of the plane of its bed is likewise lower than that of the jointer, it being increased, for soft wood only, two or three degrees; but for fine cabinet work, when the stuff is hard, it is often made so as to form an angle with the perpendicular of about fifty-five or even sixty degrees. In this case, the position of the basil is reversed, so as to be next the fore end, or in front of the stock.

The *Smoothing Plane*, (*pl.* LXIX, *fig.* 3,) without a tote, is the last plane which is made use of in giving the utmost degree of smoothness to the surface of a piece of finished work. It differs in shape from all the planes yet mentioned, being about seven inches in length, with the sides of the stock convex, so as to resemble the figure of a coffin. The smallness of this plane fits it admirably for smoothening small portions of a surface which the large planes would not be able to touch. Besides, as it is wrought like the jack-plane, in small strokes, its direction can easily be varied, so as to suit cross-grained stuff. But though it is not adapted to produce straightness of sur-

face, yet the inequalities which it may have will be so imperceptible, that it will be impossible for them to deface, in the slightest degree, the surface of desks, tables, and other furniture, even of the most finished description.

The *Tooth-Plane* is fitted with a blade or iron, on the steel side of it covered with rakes or small grooves, close to each other, and all in the direction of its length, so as to act by scraping or scratching. The stock is usually of the shape and size of the smoothing plane, and the bed of the stock, for receiving the blade or iron, is inclined only about six degrees; and thus the iron, when fixed, works almost perpendicular to the sole of the stock. Without this instrument, the workman would often find the utmost difficulty in planing many kinds of cross and twisted-grained stuffs; for, although the double iron is an excellent invention, and the use of it the best and most general remedy against curling and cross-grained stuff of ordinary quality, yet it is often found defective in working some fine specimens of mahogany, and still more of fustic. But, with the tooth-plane, let the nature and texture of the stuff be as hard and cross-grained as possible, its surface may be made every where alike, and left no rougher than if it had been rubbed over with a piece of new fish-skin; and this roughness may be easily and effectually removed with a scraper.

The *Forkstaff-Plane* is similar to the smoothing plane in size and shape; but the sole is concave, and the concavity is in the direction of the length of the plane. The use of the forkstaff-plane is to form a convex cylindrical surface, when the wood to be wrought is bent with the fibres in the direction of the curve; as the convex surfaces of the rims of carriage-wheels, or the top rails of camp-bedsteads, and work of a similar nature. Consequently, forkstaff-planes must be of various sizes, to form the surfaces of various radii.

The *Compass-Plane* is similar to the smoothing plane in every respect, as to size and shape; but the sole forms a convex surface, in order to suit itself to planing concave surfaces; and, consequently, compass-planes must be of various sizes, to accommodate different diameters.

The *Rebat* or *Rebating Plane* is used after a piece of stuff has been previously tryed on one side and shot on the other, or tryed on both sides, to

take away (by shavings) from the edge a piece, in the form of a square or rectangular prism, so as to leave a groove, consisting of two surfaces at right angles to each other. Various kinds of cornices and other ornamental work require this mode of reducing the stuff. The rebat-plane is also frequently used, as its name may show, to form a groove to receive the edge of another board, cut in like manner, so that the one may lap over the other to the breadth of the rebat, and form one even surface. From the planes hitherto described the shavings escape at the top, but in the rebating plane they escape at the side. Rebating planes are of various kinds: some have a fence to regulate the horizontal breadth; others are provided with a stop to determine the vertical extent or depth of the rebat; and some have both stop and fence, and others neither. Those rebating planes which have no fence, have the iron of the same breadth as the sole. Some have the cutting edge of the iron only on the side, and others only on the bottom of the stock: these are used for dressing and finishing off with the greatest exactness, separately, both sides of the rebat.

*Fillisters* are a sort of rebating plane, used for sinking, or cutting away, the edge of a piece of wood to form the rebat, leaving it for the others to smooth the surfaces when cut. These are represented in *plate* LXIX, *figures* 6 and 7. The first is the *Sash Fillister,* which throws the shavings off the bench: *a* denotes the head of one *stem*; *b* of the other; *c* the iron; *d* the wedge; *e* thumb-screw for moving the stop up and down; *b, f,* fence for regulating the distance of the rebat from the arris. The second, *fig.* 7, is the *Moving Fillister,* for throwing the shavings on the bench. No. 1 is the right-hand side of the plane; *a* the brass stop; *b* the thumb-screw of the same; *cde* tooth, the upper part, *cd,* on the outside of the neck, and the part *de* passing through the solid of the body, with a small part open above; *e* the tang of the iron tooth; *ee* the guide of the fence. No. 2 represents the bottom of the plane turned up; *a* the guide of the stop; *ff* the fence, showing the screws for regulating the guide; *gg* the mouth and the cutting edge of the iron.

The *Plough-Plane* (*pl.* LXIX, *fig.* 8,) is used for sinking a groove in a board, by taking away a solid in the form of a rectangular prism, so as to leave a ridge on either side. The operation of cutting with this instrument is called *ploughing*. In order to prevent the cumbersomeness and expense of being obliged to use a different plough for every different sized groove which may be required, the *Universal Plough* was invented. This instrument is provided with a fence, which has two stems, with keys and a stop, moved by a thumb-screw. The sole of this plane is the bottom narrow side of two vertical iron-plates, which are something thinner than the narrowest iron. The iron and wedge are inserted in the same manner as in the rebating planes. The fore-end of the hind plate forms the lower part of the bed of the iron, with a projecting angle in the middle, and an external angle adapted to the bed-side of each angle: thus the iron is prevented from being moved by any sudden obstruction. The fore iron-plate is cut with a cavity, similar to the common rebat-planes. The stop and fence of this universal plough being moveable, it will readily admit, according to the extent of the groove desired, the particular sized iron which will be necessary.

*Moulding Planes* are used for forming curved surfaces of the greatest diversity of contour or form, which is necessarily the reverse of the moulding of the plane. The figure of the edge of the iron, and that of the sole of the plane, should exactly correspond. Single mouldings, or different mouldings in assemblage, have various names, according to their figure, combination, or situation. Mouldings are formed either by a plane reversed to the intended section; by a fence and stop, which causes them to have the same transverse section throughout; or by several planes, adapted as nearly as possible to the different degrees of curvature. In whetting the irons of moulding planes, the greatest caution should be taken that its form is not injured thereby. The whole of the sole, or, at all events, the ridges of the moulding, particularly if the base be narrow, should be formed of box-wood, as no other wood unites, in so great a degree, the valuable properties of smoothness, toughness, and durability.

Saws.—The best saws are made of plates of tempered steel, ground bright and smooth; they are known to be well-tempered by the stiff-bending of the blade, and to be well and evenly ground by their bending equally in a bow. The back of the saw is always thinner than the edge in which the teeth are cut, in order that it may more readily follow the edge. The instrument made use of for cutting and sharpening the teeth of a saw is a triangular file; but it is necessary, in order to perform this operation well, that the blade of the saw should be fixed in a vice or whetting-block. If the teeth of the saw make the kerf or fissure barely of the width of the thickness of the saw-plate, the motion of the tool must necessarily be much impeded by friction. In order to hinder this inconvenience, when the teeth have been filed, they are turned out of the right line, alternately, first to the right and then to the left: thus, the fissure made in the wood is wider than the thickness of the plate of the saw, and thus all inconvenience from friction is avoided. The facility of cutting will moreover be greater, if the extremity of each tooth at the outside corner is left a little higher than that of the inside. The above-mentioned operation is called *setting a saw.*

The teeth of saws are usually bent with a piece of iron or steel, which has several nicks in the edge, at right angles to its length, and of various sizes. This instrument is about five or six inches long. The operation is performed in the following manner: The blade of the saw should first be fastened in a vice, in order to retain it firmly; and then, having selected the nick which will exactly fill the tooth intended to be bent, the instrument is twisted up or down, according to circumstances; and thus the effect of bending the tooth is readily and speedily produced. The teeth of a saw are made larger or smaller, according to the coarseness or fineness of the stuff which they are intended to cut. Coarse teeth would find so much resistance from hard and fine-grained wood, that additional labour would be required for the operation. The degree of acuteness required for the teeth of saws is comprised in an angle of about sixty degrees. Hence the outer arris of each tooth should be made sharp, by moving the file in a straight direction, and thus leaving the slanting sides of the teeth flat.

The front edge or apex of the teeth of saws that are used for dividing wood in the direction of its fibres, should be made standing nearly as forward as the base of the tooth on that side which is next to the lower end of the plane. But, for cutting wood transversely, or in a contrary direction to its fibres, this form would greatly hinder the operation of pushing the saw forward; and, therefore, saws used for this purpose, usually have the apex of the tooth no more forward than the centre of its base.

The operation of sharpening saws is generally performed, in large towns, by persons who get their entire livelihood thereby, and who receive no small share of praise when they perform the operation well. The persons who generally apply to them are journeymen, who do not reflect that the ingenuity which they so much praise might be acquired in less time than is wasted by carrying, looking after, and fetching, their tools; and thus, if they had nothing to pay for the work, and suffered no inconvenience from being deprived of tools which they are constantly in want of, they can still be no gainers by employing others to do that which they might themselves learn to do equally well, without any expense, and in the same portion of time.

The following is a list of the saws in common use: *viz.*

The *Pit-Saw*, a large saw, with two handles, used by sawyers in a pit, for reducing trunks of trees, &c., into boards or planks.

The *Whip-Saw.*—This saw has likewise two handles, and differs from the *pit-saw* in not being used in a pit; but still it is employed for reducing such pieces of timber as are too large to be reached by the hand-saw.

The *Hand-Saw* (*pl.* LXVIII, *fig.* 6,) has a blade or plate about twenty-six inches long, so that it can easily be made use of by the hand. It is used not only for cutting wood in the direction of the fibres, but, likewise crossways. The teeth, in general, are made about four in the inch; but, as the workman has less power in working the saw towards the first part of its course, the teeth at the lower end are made rather smaller than those towards the upper end, or broadest part, of the plate; and, by this mean, the surface and sides of the kerf are less torn than they otherwise would have been, particularly in

cross-cutting, providing the teeth had all been of the same size throughout the blade.

The *Panel-Saw* has a plate nearly of the same size as the hand-saw; but being used for cutting very thin boards in any direction, it contains about half as many more teeth, in the same length, than the hand-saw.

The *Bow-Saw*, or *Frame-Saw*, has a plate which is too long and narrow to be kept straight without a frame, and it is, therefore, furnished with cheeks, in order to tighten the plate. This is performed by twisting the cords which reach from one cheek to the other at the upper ends, by means of a tongue in the middle; for the upper ends, being thus drawn closer together, the lower ones are necessarily set farther apart, and thus the frame is tightened, and consequently the plate.

The *Tenon-Saw* (*pl.* LXVIII, *fig.* 7,) derives its name from being used for forming the shoulders of tenons; and therefore it is made so as to cut across the fibres of the wood. The largest saws of this kind are about twenty inches in length, and the smallest about fourteen inches. The size of the teeth, in this kind of saw, differs according to the length of the plate; the larger sizes having fewer teeth in the same space. The average may be from eight to ten in an inch.

The *Sash-Saw* (*pl.* LXVIII, *fig.* 8,) has a plate about eleven inches in length, and contains about fourteen teeth in the inch. It derives its name from being used for cutting the tenons of sashes.

The *Dove-tail-Saw* takes its name from being used in dove-tailing drawers, &c. The plate is in length about nine inches, and contains about fifteen teeth in an inch. The plates of the three last named saws, *viz.* the tenon-saw, the sash-saw, and the dove-tail-saw, are so thin as to require a back, in order to keep them from bending. This back is formed of a stout piece of brass or iron, with a groove, into which the back of these saws are let in; and, as these saws are not required to cut wood the whole length, this addition does not in the least hinder the process of working with them.

The *Compass-Saw* (*pl.* LXVIII, *fig.* 9,) has a very peculiar formation; for, being used to cut circular, or any other compass, kerf, and as the setting of

the teeth of a saw has a tendency to keep it in a right line, the teeth of this saw are never set. Moreover, as it would be impossible to keep a saw in a circular direction if the plate was of any width, the plate of this saw does not exceed an inch in the broadest part, and gradually diminishes to about one-quarter of an inch at the lower end. To give it a greater compass, in order to turn it, the back is generally made considerably thinner than the cutting edge: and, if the sides of the saw are not correctly flat, they should be a little concave, like a razor, to facilitate the working with them.

The *Key-hole-Saw* (*pl.* LXVIII, *fig.* 10,) is similar to the compass-saw, only much smaller, and is used for quick curves, such as key-holes. The handle is of the same shape as that of a chisel, but it is perforated through its whole length, and has a screw on one side, in order that the blade of the saw may be set at any distance within the handle, and made firm by the screw. By this mean the unsteadiness which would naturally occur from the narrowness of the blade is removed, and greater force may be used without the danger of breaking the blade. This saw is particularly useful in cutting small curves, or at the commencement of a work.

The Side-Hook, for cutting the shoulders of tenons is represented in *plate* LXIX, *fig.* 11. It is a rectangular solid of wood, with projecting knobs upon its alternate sides. Every joiner should have, at least, two side-hooks of equal size. The use of these is to hold a board fast, when its fibres lie in the direction of the length of the bench, while the workman is cutting across them with a saw or grooving-plane; or in traversing the wood, which is planing in a direction perpendicular or obliquely to the fibres.

The Square (*pl.* LXVIII, *fig.* 11,) consists of two parts, the blade and the stock, fixed together, each at one of their extremities, so as to form a right angle, both internally and externally; the interior angle being called the inner square, and the exterior one the outer square. The *blade* is a thin plate of steel, at a spring temper, of equal thickness in every part, and with the opposite edges in the direction of its length, correctly parallel to each other. The blade is made thin, in order the more readily to observe whether the edge of the square and wood coincide.

The *stock* or *handle,* which contains the mortise, or through which the end of the other piece passes, is made of considerable thickness; not only for containing the tenon of the other piece, but that it should likewise keep steady and flat when used. The inner edge of the stock, which forms one side of the interior square, is generally faced with brass. The thickness of the stock forms, on each side of the blade, a shoulder, which, being pressed against the edge of a piece of stuff, serves to keep the blade, which lies over the adjoining surface, at right angles to its arris, while a line is drawn along its outer edge. The interior square is generally made use of in order to discover whether a piece of stuff is correctly worked. This is done by the placing the sides of the square perpendicular to the piece examined, and, on pressing the brass part of the face of the stock against the edge of a rectangular piece of stuff, if the face of the board and the edge of the square perfectly coincide, the piece may be concluded to be square.

Stock and Bits.—The stock is an instrument for boring, consisting of a double crank, so that one end may rest against the workman's breast, and the other upon the wood intended to be bored. It is accompanied with several *bits,* or *cutters,* made of steel, and of different sizes. In most places remote from London these are called ***Brace and Bits.***

*The Stock (pl.* LXVIII, *fig.* 1,) is little more than a crank or hand-drill, made generally of wood, but sometimes of iron; and, at the parts most subject to wear and injure, defended by brass. It is worked as a kind of lever, to be turned round an axis swiftly by the hand, and thus giving to a piece of steel, fixed in the same axis, and sharpened at the extremity, a rotative motion, so as to cut a cylindric hole in the same direction as the axis of the stock. From the termination of the crank or winch part, two short limbs project, both in the same axis, and parallel with that part by which it is revolved. One of these limbs is connected with a broad head, rather convex externally, which is placed against the breast during the process, and is so constructed with joints as to be stationary, while all the other parts are revolving. The lower part of the other limb of the stock is of brass, which is

fixed by means of a screw passing through two ears of the brass part, and through the solid of the wood. This brass part is called the *pod,* and is furnished with a mortise, in the form of a square pyramid, for receiving different pieces of steel, which are secured by means of a spring in the pod, which falls into a notch at the upper end of the inserted steel piece.

*Bits* are those pieces of steel which are inserted in the pod; they are of various shapes, to suit different purposes, being used for boring and widening holes in wood, and counter-sinking, both in wood and in metals.

The *Gouge-bit,* or *Pin-bit,* is similar in shape to the turner's gouge. It has an interior cavity, like a spoon, at the extremity, for receiving the core separated from the wood by the under edge. The basil is on the inside, and the sides are brought to a cutting edge, like those of a gimblet. The section of this bit is the figure of a crescent. It is used for boring small holes in soft wood, which it does with greater rapidity than any other tool.

The *Centre-bit* is constructed with a small conical point or centre, projecting from the lower end, nearly in the middle, for entering the wood first, and keeping the tooth of the bit in its proper direction, by which a straight hole is bored with greater facility. On one side of the narrow vertical surface of the bit there is a projecting edge which inclines forward; and, on the other side, a tooth with a cutting edge, somewhat more prominent than the cutting edge on the other side of the centre. The horizontal section of this bit upwards is a rectangle. It is used to form a cylindric excavation, by cutting out a core in a spiral-formed shaving. Centre-bits are of various sizes, to suit bores of different diameters.

The *Taper-shell-bit* is used for widening holes, and differs but little from the gouge-bit, except in tapering gradually from the pod to the lower extremity. It is conical within and without, and the cutting edge is the meeting of the exterior and interior conic surfaces. Its horizontal section is a crescent.

The *Countersink* is used for widening the upper part of an excavation for receiving the head of a screw. It has a conical head, and when used for wood

has a single cutter, the edge of which stands out a little from the side of the cone, so as to be more remote from the axis of the cone than from any other part of the surface. For boring holes in brass, the countersink is furnished with ten or a dozen teeth on the surface, running slantwise from the base up the sides of the cone, so that the horizontal section represents a circular saw. The countersink is sometimes made use of for wood, especially when it is hard; as its teeth act like those of a file, and consequently are less liable to tear the surface of the wood than the shell bit, which has a cutting edge.

The STRAIGHT EDGE is a piece of stuff or board, made perfectly straight on the edge, and used to plane the face of a board straight by, or to make other edges straight. Straight edges should be made of the best seasoned stuff, and it is customary to make two at the same time, after the following method: Take two pieces of stuff, of equal thicknesses, with the sides true; and, having placed them side by side, fasten them in the cheeks of the bench-screw, and plane the upper edges straight by means of a straight edge; or, if this cannot be readily obtained, as nearly true as can be determined by the eye. The two pieces are then taken out of the screw, and placed with the edges one upon the other; and, if the surfaces coincide so exactly as not to permit any light to pass between, the straight edges are finished; but if there is any roundness or hollow in them, they must again be shot; and this operation must be repeated as often as found necessary, that is to say, till the faces of the boards are in a straight line with each other.

WINDING STICKS are always used in pairs, and are two pieces of wood, of equal breadth, used for the purpose of determining whether a surface be straight or not. Winding sticks differ from *straight edges* in this, that straight edges are seldom finished on more than one edge, whereas if both edges were made so correctly rectangular, that they were of the same breadth throughout their whole length, they would answer the end, and in fact be winding sticks, which are used in the following manner: The edges of a pair of winding sticks are applied, one at one end of the surface to be examined, and the other at the other end; from the uppermost edge of the nearer one, the eye

is then directed to that perpendicular side of the farther one which faces the observer, and if straight lines can be directed from it to all the other points in the upper edge of each winding stick, the ends of the surface examined are already in the same plane. But, if the nearer winding stick will not permit the eye to be directed in a straight line to any one point in both winding sticks, the surface is said to *wind*, and the part found to be too high must be reduced. The winding sticks, for greater certainty, should be placed in various situations, but particularly across the corners, so that the eye may examine them diagonally.

# CHAPTER V.

REMARKS ON, AND INSTRUCTIONS FOR CHOOSING, THE DIFFERENT SORTS OF TIMBER; THE RELATIVE STRENGTH OF TIMBER, AND MODES OF ASCERTAINING IT; THE SCARFING AND COMBINATION OF BEAMS; THE FORMATION OF THE CENTRING OF ARCHES, AND THE CONSTRUCTION OF TIMBER-BRIDGES, &c.

## I.—QUALITIES OF TIMBER.

OAK.—In our general description of the properties of timber we shall begin with the OAK, a tree which, from its strength, hardness, and durability, has obtained the pre-eminent distinction of 'KING OF THE FOREST,' and is common to almost all the countries of the earth.

On selecting a piece of oak, which shall have the greatest strength, or durability, it is often found to be a criterion of its excellence that it has grown on a soil which reared it slowly; as, in this case, it acquires from time a greater consistence of strength than it would acquire were it reared on soil of such a quality as to bring it hastily to maturity. This, however, is not always the case: because, from particular exposures, a tree of oak may acquire a strength and hardness sufficient to undergo the greatest pression, although it has sprung from a mere acorn to a tree of "loftiest grandeur" in a very few years.

This is not mere conjecture; for we know, from certainty, that the oaks on the estate of Roxburgh, in Scotland, for stature, for strength, and resisting quality, are not excelled by the oak of any other growth in Britain, and a very

few years are requisite for bringing it to full maturity; but, even on this estate, there is a very great difference in the quality of the oak: that which has northern exposure is found to be more strong and hardy than that which inclines to the sun at noon-day.

Another criterion is, to select that which, on being soaked in water, shall have its specific gravity the least changed. This is evident, because the closeness of the fibres being sufficient to prevent the entrance of the fluid must likewise, in this situation, indicate the strength of the wood. This observation is not confined to oak, but may be generally applied to timber of every description.

In selecting trees for felling, we must be particular in examining the state of health of those trees to which the axe is to be applied; for, if decay has taken place, we are sure that the timber is not so proper for our purpose as it would otherwise be. When the top of the tree is in a state of decay, it clearly bespeaks a decay in the tree itself; and, if a branch be decayed, or a stump rotten, it indicates a defect in that part of the tree to which it is attached.

Another circumstance to be particularly attended to, is, the time of cutting; the purposes of building requiring the greatest perfection of strength and texture, it is found necessary to cut down the tree in winter, when it is freest from sap; as, in this case, it is more readily seasoned and rendered fit for use.

It, however, seldom happens that oak is cut down in winter; its bark being so valuable and useful in the tanning of leather, that it is found to be more profitable to the owner to reserve the tree till spring, when the sap has, in ascending from the root, loosened the bark from the wood, so that it may be easily stripped off; which it would not be were it cut down in winter.

The difference of seasons sometimes occasions a difference in the time of felling the wood, even for this purpose; but what ought to be particularly attended to, is, the state of the leaf. After the leaf begins to appear is a very proper time; for then the sap has expanded all round and over the tree, so that the bark is easily removed; if delayed till the leaf be fully expanded, the bark loses considerably in its value.

In the progress of decay, it has been observed that, the outer coat, being exposed to the action of the atmosphere, is first destroyed; then the second coat, and so on, gradually approaching the centre or heart of the tree: but we must understand this only of those trees which have been cut before they had reached their prime; as those that from age suffer decay have their central part first destroyed, and the outer shell will even stand many years after the inner parts have been entirely wasted.

A skilful builder will, therefore, if the tree be old and large, be very particular in examining the central parts; especially that which lies next the root, as there the wasting will first begin.

For seasoning oak, the best method is to immerse it in water; this, in logs, should be done for more than twelve months; but, if cut into planks, so much time is not necessary. In either case, to soak and dry alternately is to be preferred. The seasoning of planks can thus be always effected without much trouble; but, with respect to logs, on account of the vast labour required, one soaking and again drying gradually in the shade is generally practised.

After having soaked the *planks* in water, the usual mode of drying them is by placing a strong beam horizontally, so high as to admit one end of the plank to rest upon it, while the other meets the ground in an inclined position; observing to place the planks edgewise, and alternately on one side of the pole and the other, thus leaving a space between them for the air to pass freely.

BEECH.—Having said thus much in regard to oak, we shall now apply our observations to Beech, a wood which, from its hardness, closeness, and strength, especially when exposed to particular strains, holds a prominent place among the trees of the forest.

Of Beech there are three kinds; a black, a brown, and a white. The brown is very common in Britain, and is most generally found in hedge-rows, or in the demesne lands about gentlemen's seats; being, when in full foliage, remarkable for its close shade and cooling qualities.

About Mount Stuart, in the Isle of Bute, some of the trees in the avenues are immensely large, and appear to be in a thriving healthy condition; it is,

therefore, probable that the soil necessary for rearing this wood ought not to be of the richest and heaviest kind; for here, where it is found in the greatest perfection that we remember to have seen it in any place, during a tour of the kingdom, the soil is not remarkable for either of these qualities.

With respect to the nature of the other kinds we cannot say much, not having had an opportunity of examining them.

This wood is not well adapted for beams, because very little dampness soon brings on the rot; its principal use is for furniture, or for those purposes that require it to be continually under water.

ASH is a species of wood very common in Britain, and for the purposes of the farmer there is perhaps none more valuable; oak itself not excepted. Carts, ploughs, harrows, and indeed almost all the implements of husbandry, are made of this wood. Like the oak, it requires particular exposures to render it the fittest for use, where great strains have to be overcome. A clayey soil has been found to answer very well for its propagation. On the lands of Limlaws, the property of Robert Ker, Esq. of Chatta, in Roxburghshire, there is a plantation of this wood, overhanging the precipitous banks of the Tiviot, and having a northern exposure: the trees in this plantation are immensely tall, straight, and tapering upwards, like a larch; the soil is clayey, and the wood is of the best quality imaginable, producing, at times, from 1½d. to 2d. per foot more to the proprietor than the same wood of any other growth in the north.

On the demesne of Rokeby, near Greta Bridge, in Yorkshire, are trees of ash, very large and goodly to appearance, but we have not been able to ascertain any thing respecting the nature and particular qualities of the wood.

On the estate of Marchmont, in Berwickshire, are ash trees of very great size, which sufficiently prove that this wood is of a towering nature, although, on account of the many uses to which it is applied, it seldom arrives at maturity. The proper time to cut down ash is in winter, when the sap is lodged in the root.

The quality is nearly the same through the whole thickness of the tree, but the outside is rather the toughest. It soon rots when exposed to the weather,

but will last very long if properly taken care of. It is of a spongy consistence; and that of which the fibres are long and straight is always considered the best.

ELM is another tough and strong species of wood; it is, also, very useful for the husbandman, many implements being made of it; and, indeed, it is often preferred, for particular purposes, to ash itself. This is a very common wood, and is mostly found in hedge-rows, or around the skirts of plantations. On the demesne lands of Springwood Park, in the neighbourhood of Kelso, trees of this kind are very large, high, and branching, and contain a very great quantity of valuable substance. This circumstance authorises us to conclude, that a rich and loamy soil is the best for its production; as, in this particular place, the land is of such a quality, and also extremely fertile, the elms reared on it may be compared with any in the kingdom.

FIR.—The next species to which our attention shall be directed is FIR, than which there is no kind of timber more useful, or applied to so many purposes. This, however, arises, not from its superior strength or durability, but from its cheapness, and yielding easily to the tools of the workman. It is common in almost all northern countries, and is brought, in great quantities, from Norway, Russia, Sweden, and North-America.

The fir which is mostly used in carpentry is distinguished by the name of *Memel Fir*, and includes that of Dantzic and Riga. *Norway Fir* is much used for smaller timbers, and answers extremely well when exposed to the air, or when kept under ground. The fir from North-America is softer than any just mentioned; it is likewise freer from knots, and, of course, suitable for the finer parts of joinery, such as panels and mouldings. What is termed in England *white deal*, and in Scotland *pine wood*, is very durable when kept dry, and for that reason is much used by cabinet-makers; but, as it does not stand the weather, it is but little used in carpentry or joinery.

In former times the Highlands of Scotland abounded in forests of fir-trees, as appears from the great number of stumps and roots still existing in the bogs and morasses. Above Lochiel House, in Invernesshire, along the whole



*Errata.* In the last two lines of page 243, for the sentence as printed, read *jointer and smoothing plane, but not in any* [illegible]

extent of Loch Aghrigh, or Arkeig, is a forest of fir, in which many of the trees are yet in a high state of health, and of a great size: this wood is very strong, and so full of rosin, that many of the inhabitants use it in lieu of candles, it giving such a brilliant light as to render the use of tallow unnecessary.

BIRCH is also a very common wood, and in the North of Scotland the dwarf kind grows spontaneously, in great abundance. The quality of birch is nearly the same quite across the tree; it is very tough, but cannot stand the weather, and worms are very hurtful to it. Birch is often used in works which lie under water.

POPLAR is a tree that thrives well on wet ground, and is very often found on wet spots about the seats of gentlemen. In beams it is liable to the same objections as beech, but it is well adapted for floors and stairs; it rots when exposed to the weather.

The poplar and the asp resemble each other; the latter is tough and soft, lasts when exposed to the weather, and is equally good through the body of the tree.

SYCAMORE and LIME.—In roofing and flooring the SYCAMORE and LIME are subject to the same objections as the beech and poplar. The lime is, however, suitable for furniture; being, like the ash, smooth and greasy when wrought.

WALNUT and CHESNUT.—We have also the WALNUT-TREE and the CHESNUT; the former of which has become too valuable, in Britain, to be used in the common purposes of framing roofs or floors; and mahogany has superseded its use in furniture.

There are different kinds of Chesnut. The Spanish or Sweet Chesnut is frequently found in old buildings in England; it is very like oak, and is often confounded with it; but, notwithstanding, it differs from it in this, that, when a nail or bolt has been driven into oak before it was dry, a black substance appears round the iron, which in chesnut is not the case.

MAHOGANY is chiefly used in furniture, and sometimes also in doors and window-sashes; it is sawn out and seasoned by being kept in the open air

in winter: it is extremely valuable, and grows in Jamaica. There is another kind, from Yucatan, called *Honduras mahogany*, but that of Jamaica is much the most beautiful and durable. The pores of the Honduras appear quite black; those of the Jamaica as if filled with chalk.

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## GENERAL CAUTIONS AND REMARKS RESPECTING TIMBER.

Lay your timber up, when perfectly dry, in an airy place, that it may not be exposed to the sun and wind, and taking care that it do not stand upright, but let it be laid along, one piece upon another; interposing, here and there, some short blocks, to prevent that mouldiness which is usually contracted when the planks sweat.

Some persons, however, keep their timber as moist as they can by submerging it in water, with a view to prevent it from cleaving. This is good in fir, and also in some other timbers, both for the better stripping and seasoning. Lay your planks in a stream of running water for a fortnight, and then set them up in the sun and wind, so that the air may freely pass between them, and turn them frequently. Boards thus seasoned will floor much better than those which have been kept many years in a dry place.

But, to prevent all possible accidents, when you lay your floors, let the joints be fitted and tacked down only for the first year, nailing them close down the next; and, by this method, they will lie without shrinking in the least.

Amongst wheelwrights, the water-seasoning is of special regard, and of such esteem amongst some, that the Venetians lay their oak some years in water before they employ it.

Elm felled ever so green, if kept four or five days in water, obtains a good seasoning, and is rendered fit for immediate use. This water-seasoning is not only a remedy against the worm, but it also prevents distortions and warping. Some persons recommend burying in the earth, and others will

have their timbers covered-in to heat; and we likewise see that scorching and hardening in the fire renders piles durable, especially those which are to stand in earth or water.

Green timber is sometimes used by those who carve and turn; but this for doors, windows, floors, and other close works, is altogether to be rejected; especially if walnut be the material, which will be sure to shrink. It is, therefore, best to choose such as has had two or three years' seasoning, and which is neither too dry nor moist.

Where huge massy columns are to be used, it is a good plan to bore them right through, from end to end, as it prevents their splitting.

Timbers occasionally laid in mortar, or in any part contiguous to lime, as doors, window-cases, ground-sils, and the extremities of beams, &c., have sometimes been capped with melted pitch, as a preserver from the destructive effects of the lime; but it has been found to be rather hurtful than otherwise.

For all uses, that timber is the best which is the most ponderous and free from knots. As to the place of growth, that is generally esteemed the best which grows most in the sun; but, as we have already hinted, this is not always the case. The climate, however, contributes much to its quality, and a northern situation is preferable to all others.

## II.—ON THE STRENGTH OF TIMBER.

The strength of materials used in mechanical constructions is exerted in five different ways; that is to say, in resisting a direct pull, in compression, in a transverse strain, in torsion, or a twisted state, and in percussion.

The strength which *resists extension* is the result of cohesion, as opposed to another force, called *repulsion.* To conceive this, we must imagine that each particle of a body is at some distance from the rest, and if they be forced to approach within this limit, repulsion is exerted. If cohesion opposes the extension, both act according to the same law, being as the extension or compression, while the forces exerted are not

great. They differ, however, in this, that there is a certain limit beyond which cohesion does not act; and if it be exceeded, a total separation takes place, while there seems to be no limit to the compressibility of matter.

*Cohesive strength,* in prismatic bodies, is proportional to the transverse section, or area of either end, and is measured by the weight required to tear them asunder. In those substances, however, which possess ductility, the surface of fracture is not the true surface whose cohesion is overcome by the weight; they stretch considerably on the first application, and their diameter is gradually contracted until they yield. The force, therefore, required to tear them asunder suddenly, is much greater than what they can bear for a length of time; even iron, which suspends twenty-seven tons for every inch of its section, cannot be trusted in any structure with more than fifteen tons: hard steel, that cannot be stretched, is far stronger; bearing nearly eighty tons.

Experiments on timber are much more irregular than those on metals, from the irregularity of its fibres; there is also a considerable variety of specimens from the same tree. Oak bears about four tons per inch, and fir two and a half. Where a rod, used to suspend a body, is of considerable length, its weight must be added to the load, and therefore the section should be continually less downwards.

The strength of bodies to resist compression is much more difficult of investigation, and the greatest analysts have been mistaken in their results. There is no relation between cohesive and repulsive forces. Fir, which suspends little more than half as much as oak, will carry twice as much; and it is said that cast iron resists compression with a force six times greater than its cohesion. In a rectangular beam, if the compressive force be not applied in the direction of the axis, it will bend the beam; for the repulsive forces, acting against it on each side of a line, drawn through the point of application, must be equal; but the number of particles between it and the surface nearest to it, is less than that of the rest of the section; and if they were equally impressed throughout, their action could not be equal to that of the

others; they must, therefore, be more compressed, which augments their repulsion, and compensates for inferiority of number. The column, therefore, must bend, as one of the surfaces becomes shorter than the other, and there is a longitudinal section, which is neither compressed nor extended, which has obtained the appellation of *Neutral Section.*

Between this section and the remote surface a portion of the beam is in a state of extension. It is obvious that a similar flexure would be produced by a force applied obliquely to the axis, or by a transverse strain, even when it acts directly, and that the strength is much increased if it be prevented from bending by lateral braces applied at its middle.

A piece of timber projecting from a wall, in which it is fixed, may be strained or broken by a weight suspended from the extremity, as in *fig.* 1, *plate* LXX, or by a load uniformly distributed over it, as in the cantalivers of a roof.

*Figure* 2 exhibits a piece of timber in the act of breaking; the bar being supposed to move round the point A; the fibres above, from A to CD, are supposed not to be broken, they are therefore in a state of tension, and the fibres below the point A, from A to B, are in a state of compression: both these forces equally counteract the efforts of the weight W; the force of extension being equal to that of compression.

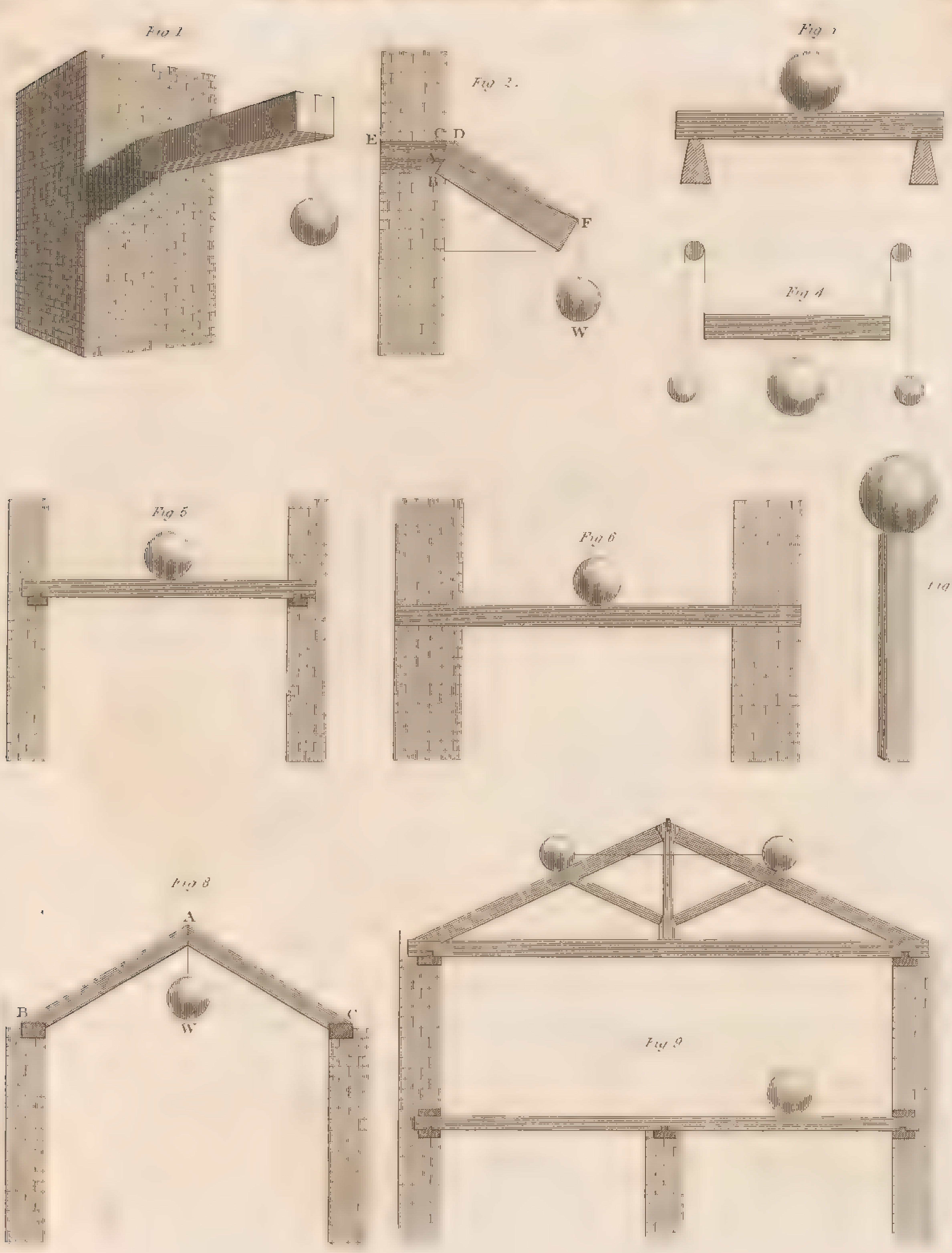
*Figure* 3 exhibits the manner in which a beam, supported at both its extremities, may be broken by the application of a force in the middle, or between its ends, as in case of joists, binding beams, and girders, which have not only to sustain their own weight, but more commonly any accidental weights with which they may be loaded.

This manner of exposing timber to fracture is the same as that represented at *fig.* 4, where the weights are substituted for the props and made to pull upwards, each weight being equal to half the weight suspended in the middle.

*Figure* 5 represents a joist supported by two walls. We must here observe, that joists ought never to be firmly fixed in walls when they are inserted only nine or ten inches, as in common cases; for they would endanger the wall by causing it to bend or fracture, particularly when the wall is thin: however,

# ON THE STRENGTH OF TIMBER.

*PLATE LVI.*




*Designed by W. Turnbull.*

*Engraved by H. Adlard*

*London Published by Thos. Kelly, 17, Paternoster Row, May 29th 1824*

when it is of sufficient thickness, and timber inserted the whole thickness, as in *fig.* 6, the effort to bend or fracture the wall will not take place, and the timber, thus fixed, will be exceedingly stiff, the strength being increased.

A joist, as in *fig.* 6, reaching over two areas of equal breadth, is much stronger than a joist of the same scantling, reaching over one area of the same breadth.

*Figure* 7 exhibits another way in which timber may be broken, by being crushed, as in the case of columns, strong posts, principal rafters, &c.

In *figure* 8, which represents a pair of rafters, supported on two opposite walls, a weight, W, suspended from the vertical angle A, compresses the rafters AB, AC, in the direction of their lengths.

*Figure* 9 shows the efforts of two equal weights to break the rafters; but this is prevented by two struts, branching from the king-post to a point in the rafter under the place where the force is applied. The effect of the weight is, therefore, to crush both rafters and struts. For a force applied upon the back of a rafter presses in the direction of the struts, which again press on the lower end of the king-post, and the king-post presses on the tops of the rafters, the lower ends of which press the extremities of the tie-beam, which is therefore brought into a state of tension. The rafters are in a state of compression, and the king-post in a state of tension, while the struts are in a state of compression.

With regard to *cohesion*, the strength is as the number of ligneous fibres, and therefore as the area of fracture; but, in transverse strains, the case is very different, where, instead of a direct application of the force in the line of the fibres, it is able only to act upon them alternately, in the direction of the fibres, by means of levers.

Galileo, to whom the physical sciences are so much indebted, was the first who undertook to investigate the subject upon pure mathematical principles. He considered solid bodies as being made up of numerous small fibres, applied parallel to each other: he assumed the force which resisted the action of power to separate them, to be directly as the area of a section perpendicular to the length: that is, as the number of fibres of which the

body is composed: he likewise assumed the non-extension and compression of bodies, and therefore the whole resistance to fracture of a rectangular beam, turning a line in one of its sides perpendicular to the two edges, was the same as if the whole resistance had been comprised in the centre of gravity.

Now, in a rectangular beam, the centre of gravity is distant from the axis half the depth of the beam. Therefore, let $b$ be the breadth, and $d$ the depth, of the beam; then the distance of the centre of gravity will be $\frac{1}{2}d$, and the effort to resist fracture will be $bd \times \frac{1}{2}d = \frac{bd^2}{2}$.

Therefore, when a beam is solidly fixed in a wall, if $l$ be the length, $w$ the weight that will break it:

$$\text{Then } w : bd :: \tfrac{1}{2}d : l. \quad \text{Whence } w = \frac{bd^2}{2l}.$$

From other investigations, which we shall not attempt to show here, the author endeavours to prove that, whatever weight is required to break a beam fixed at one end, double that weight is necessary to break a beam of equal breadth and depth, with twice the length, when supported at both ends.

But *Marriotte*, a Member of the French Academy, having discovered the inaccuracy of Galileo's theory, proposed to substitute another in its place. This attracted the attention of the philosopher *Leibnitz*, who concluded that every fibre, instead of acting with an equal force, exerted a power of resistance proportional to the distance of extension, but he still considered the fibres to be incompressible, or that the beam turned on the point where the fulcrum was applied. The only alteration introduced by this new hypothesis was the removal of the centre of energy.

The complete investigation of the resistance of materials, according to the direction and situation of the forces applied, would require a volume. The reader who wishes for full information on this subject, cannot do better than consult Mr. Barlow's valuable "Essay on the Strength and Stress of Timber."

Let, as before, $l$ denote the length, $b$ the breadth, and $d$ the depth, of a rectangular beam, all in inches; W the weight with which it is loaded in the

middle (being supported at both ends), $\delta$ the deflection, and E the measure of the elasticity, then it will be found that

$$\frac{Wl^3}{\delta b d^3} = E, \text{ is a constant quantity for the same timber;}$$

or, which is the same thing,

$$\frac{Wl^3}{E b d^3} = \delta.$$

This formula is equally applicable to beams fixed at one end and loaded at the other, and those which are supported at both ends and loaded in the middle, only the value of E, in the one case, will be to that in the other, as 32 to 1.

The theorem for ascertaining the ultimate deflection of beams, before absolute rupture, is

$$\frac{l^2}{d\Delta} = U.$$

If the resistance of a rod, an inch square, be S, then $bd^2$S will be the resistance of a beam of the same length, whose breadth is $b$, and depth $d$; also, if the angle of deflection be $\Delta$, and the breaking weight W, then, when the beam is fixed at one end, and loaded at the other,

$$lW \cos. \Delta = bd^2 S, \text{ or } \frac{lW \cos. \Delta}{bd^2} = S, \text{ a constant quantity.}$$

When the beam is supported at both ends and loaded in the middle,

$$\tfrac{1}{4} lW \sec^2 \Delta = bd^2 S, \text{ or } \frac{lW \sec^2 \Delta}{4bd^2} = S, \text{ constant.}$$

When the beam is fixed at each end and loaded in the middle,

$$\tfrac{1}{8} lW \sec.^2 \Delta = bd^2 S, \text{ or } \frac{lW \sec.^2 \Delta}{bd^2} = S, \text{ constant.}$$

When the beam, in either of these last cases, is loaded at any other point than the middle: we shall have, in the first case, (denoting the unequal lengths by $m$ and $n$)

$$\frac{mnW \sec.^2 \Delta}{l} = bd^2 S, \text{ or } S = \frac{mnW \sec.^2 \Delta}{bd^2 l};$$

and, in the second case,

$$\frac{2\,mnW \sec.^2 \Delta}{3\,l} = bd^2 S, \text{ or } S = \frac{2\,mnW \sec.^2 \Delta}{3\,bd^2\,l},$$

still the same constant quantity.

The first formula will also apply to a beam fixed at any given angle of inclination; observing only that the angle $\Delta$, in this case, will represent the angle of the beam's inclination, increased or diminished by the angle of

deflection, according as its first position is ascending or descending; or, rather, it will denote the angle of the beam's inclination at the moment of fracture.

For all cases, when it is only intended to apply the results to timbers used in architectural and other purposes, the angle of deflection may be omitted, and the equations will become simply

$$\frac{lW}{bd^2}=S,\ \frac{lW}{4\,bd^2}=S,\ \frac{lW}{6\,bd^2}=S,\ \frac{mnW}{lbd^2}=S,\ \frac{2\,mnW}{3\,lbd^2}=S.$$

The absolute cohesion on a square inch is

$$C=\frac{S'd^2}{(d-D)^2}$$

where D is the depth of the neutral axis, or the line which separates the compressed from the stretched part of the timber.

The subjoined table of data, for different kinds of wood, results from the union of the preceding formulæ, with experiment.

| Name of the kind of Wood. | Specific Gravity of each kind | Value of U from the formula $U=\frac{l^3}{d\Delta}$. | Value of E from the formula $E=\frac{l^3W'}{bd^3\delta}$. | Value of S from the formula $S=\frac{lW}{4\,bd^2}$. | Value of S from the formula $S'=\frac{lW sec.^2\Delta}{4\,bd^2}$ | Value of C from the formula $C=\frac{S'd^2}{(d-D)^2}$. |
|---|---|---|---|---|---|---|
| Teak | 745 | 818 | 9657802 | 2462 | 2488 | 15550 |
| Poon | 579 | 596 | 6759200 | 2221 | 2266 | 14787 |
| English Oak | 934 | 435 | 5806200 | 1672 | 1736 | 10853 |
| Canadian Oak | 872 | 588 | 8595864 | 1766 | 1803 | 11428 |
| Dantzic Oak | 756 | 724 | 4765750 | 1457 | 1477 | 7386 |
| Adriatic Oak | 993 | 610 | 3885700 | 1383 | 1409 | 8808 |
| Ash | 760 | 395 | 6580750 | 2026 | 2124 | 17337 |
| Beech | 696 | 615 | 5417266 | 1556 | 1586 | 9912 |
| Elm | 553 | 509 | 2799347 | 1013 | 1042 | 5767 |
| Pitch-Pine | 660 | 588 | 4900466 | 1632 | 1666 | 10415 |
| Red-Pine | 657 | 605 | 7359700 | 1341 | 1368 | 10000 |
| New-England Fir | 553 | 757 | 5967400 | 1102 | 1116 | 9947 |
| Riga Fir | 753 | 588 | 5314570 | 1108 | 1131 | 10707 |
| Ditto, second specimen | 738 | --- | 3962800 | 1051 | 1081 | ----- |
| Mar Forest Fir | 696 | 588 | 2581400 | 1144 | 1168 | 9539 |
| Ditto, second specimen | 693 | 403 | 3478328 | 1262 | 1310 | 10691 |
| Larch | 531 | 411 | 2465433 | 853 | 890 | ----- |
| Ditto, second specimen | 522 | 518 | 3591133 | 832 | 850 | ----- |
| Ditto, third specimen | 556 | 518 | 4210830 | 1127 | 1149 | 7655 |
| Ditto, fourth specimen | 560 | 518 | 4210830 | 1149 | 1172 | 7352 |
| Norway Spar | 577 | 648 | 5832000 | 1474 | 1492 | 12180 |

## PROBLEMS.

### PROBLEM 1.

To find the strength of direct cohesion, of a piece of timber, of any given dimensions.

Rule.—Multiply the area of the transverse section, in inches, by the value of C in the preceding table of data, and the product will be the strength required.

*Note.*—If the specific gravity be not the same as the mean tabular specific gravity, say, as the latter is to the former, so is the above product to the correct result.

#### EXAMPLES.

*Example* 1.—What weight will it require to tear asunder a piece of teak three inches square, the specific gravity being 745?

| | |
|---:|---|
| Here 15550 | is the tabular value of C. |
| 9 | the area of the section. |
| 139.950 | lbs. the weight sought. |

*Example* 2.—What weight will break a cylinder of ash two inches in diameter, the specific gravity being 700?

| | |
|---:|---|
| .7854 | |
| 4 | |
| 3,1416 | area of section. |
| 17337 | tabular value of C. |
| 219912 | |
| 94248 | |
| 94248 | |
| 219912 | |
| 31416 | |
| 54465,9192 | the weight in lbs. very nearly. |

760 : 700 :: 54466 : 50166 lbs.

| |
|---:|
| 54466 |
| 700 |
| 760) 38126200 (50166 |
| 3800 |
| 1262 |
| 760 |
| 5020 |
| 4560 |
| 4600 |
| 4560 |
| 40 |

---

### PROBLEM 2.

To compute the deflection of beams fixed at one end, and loaded at the other, with any given weight.

Rule.—Divide the continued product of the cube of the length in inches, the given weight in lbs., and the number 32 by the continued product of the tabular value of E, the breadth and cube of the depth in inches, and the quotient will be the deflection required.

*Note* 1.—The same rule will apply if the beam is uniformly loaded, by employing the constant number 12 instead of 32.

*Note* 2.—If the specific gravity of the given pieces do not agree with the tabular specific gravity, we must operate as taught in the note to problem 1.

### EXAMPLES.

*Example* 1.—An ash batten, three inches square, is fixed in a wall, and projects from it four feet. If a weight of 200 lbs. be hung on its extremity, how much will it be deflected?

6580750 tab. value of E.<br>
$81 = 3^3 \times 3$.

6580750<br>
52646000

533040750 first product.

Again, 4 feet $= 48$ inches.<br>
$48 \times 48 \times 48 = 110592$.

Therefore 110592<br>
200

22118400<br>
32

44236800<br>
66355200

533040750) 707788800 (1.3, or $1\frac{1}{3}$ inches, nearly.<br>
533040750

1747480500<br>
1599122250

*Example* 2.—What would the same beam be deflected if supported by a prop at half its length?

*Note.*—We know that the deflections of beams of the same scantling are as the cubes of the lengths; therefore, since the prop reduces the beam to half its length, we have

$$4^3 : 2^3 :: 1\tfrac{1}{3} : \tfrac{1}{6} \text{ of an inch, the answer.}$$

That is, $4^3 = 64$

$2^3 = \ \ 8$

Therefore $8 \times 1\frac{1}{3} \div 64 = \frac{1}{6}$.

*Example* 3.—A batten of New-England fir, six feet long, four inches deep, and two and a half inches in breadth, is fixed at one end, and loaded uniformly throughout its length with 200 lbs.; how much will its extremity be deflected?

$$\begin{array}{rr}
\text{Tabular value of } E = & 5967400 \\
bd^2 = & 160 \\
\hline
 & 358044000 \\
 & 5967400\phantom{0} \\
\hline
 & 954784000 \\
\hline
\end{array}$$

Again, 6 feet = 72 inches.

$$\begin{array}{rr}
72^3 = & 373248 \\
 & 200 \\
\hline
 & 74649600 \\
 & 12 \\
\hline
\end{array}$$

$$\begin{array}{rl}
954784000) & 8957952000\,(.9 \text{ inch, or 1 inch, nearly.} \\
 & 8593056000 \\
\hline
 & \phantom{0}364896000 \\
\hline
\end{array}$$

### PROBLEM 3.

To compute the deflection of beams supported at each end, and loaded in the middle, with any given weight.

RULE.—Divide the product of the cube of the length in inches, and the weight in lbs., by the continued product of the three numbers, viz., the

tabular value of E, the breadth and cube of the depth, both in inches, and the quotient is the deflection sought.

### EXAMPLES.

*Example* 1.—A square beam of English oak, whose side is six inches, is supported on two walls twenty feet distant, and is loaded on the middle with 1000 lbs.; how much will it be deflected?

```
   5806200  tabular value of E.
      1296 = bd³.
  --------
  34837200
 52255800
69674400
----------
7524835200
----------
```

Again, 20 feet = 240 inches.

```
                  240
                  240
                -----
                57600
                  240
              -------
              2304000
             115200
             --------
             13824000
                 1000
             --------
7524835200) 13824000000 (1.8
             7524835200
             -----------
             62991648000
             60198681600
             -----------
              2792966400
             -----------
```

*Example* 2.—A beam of red pine, eight inches in breadth, and one foot deep, is supported on two walls, distant thirty-three feet four inches; how much will it be deflected with 2000 lbs. suspended at its centre?

```
     7359700  tabular value of E.
       13824 = 12³ × 8
    --------
    29438800
   14719400
  58877600
 22079100
 7359700
------------
101740492800
------------
```

Again, 33 *ft.* 4 *in.* = 400 inches,
and $400^3 = 64000000$

```
        2000
------------
128000000000
------------
```

Let, now, a number of these cyphers be rejected, and an equal number of places from the divisor, and we shall have—

```
10174) 12800 (1.25 inches, nearly.
        10174
        -----
         26260
         20348
         -----
          59120
          50870
          -----
```

PROBLEM 4.

To compute the deflection of beams supported at each end, and loaded uniformly throughout their length with a given weight.

Rule.—Compute the deflection as before, and five-eighths of the result will be the answer.

EXAMPLES.

*Example* 1.—A uniform bar of Adriatic oak, two inches square, is rested upon two pillars, distant twenty-four feet; how much will it be deflected by its own weight, its specific gravity being 960, or 60 lbs. to a cubic foot?

```
Tabular value of E is  3885700
                            16 = 2 × 2³
                       --------
                       23314200
                       3885700
                       --------
                       62171200
                       --------
```

The above data give 40 lbs. for the weight of the bar, and

$24 \text{ feet} = 288 \text{ inches}.$

```
      288³ = 23887872
                   40
             --------
621712) 9555148,80(15.36
        621712         5
        -------    -----
        3338028  8) 76.80
        3108560     -----
        -------      9.6   inches, nearly.
         2294688
         1865136
         -------
          4295520
          3730272
          -------
```

*Example* 2.—A beam of Riga fir, twelve inches square, is to support the brick-work over a gateway, twelve feet wide; the computed weight of the brick-work is 30,000 lbs.; what deflection may be expected?

```
 4638685  mean tabular value.
   20736 = 12 × 12³.
 ___________
   27832110
  13916055
 32470795
92773700
___________
96187772160
___________
```

```
     Again, 12 = 144.
   144³ = 2985984
              30000
         ____________
9618) 8957,9520000(.93
      86562          5
      _____         ___
       30175     8) 465
       28854        .58 in. nearly.
       _____
        1321
```

*Note.*—When the beam is fixed at each end, the deflection will be two-thirds of that found by rule.

### PROBLEM 5.

To compute the ultimate deflection of beams before rupture.

RULE.—Multiply the value of U, found in the table of data, by the depth of the beam in inches, and divide the square of the length, also in inches, by that product, for the ultimate deflection sought.

### EXAMPLES.

*Example* 1.—A square inch rod of ash, six feet long, is broken by a weight applied to its centre; how much is it deflected before rupture?

```
     395 tabular value of U.
       6 feet = 72.
          72² = 5184.
395) 5184 (13.1 inches, nearly.
     395
     ____
     1234
     1185
     ____
       490
       395
       ___
        95
```

*Example* 2.—What will be the ultimate deflection of a similar rod, twelve feet long?

Here 12 feet = 144 inches.

$144^2 = 72^2 \times 4 = 20736.$

```
395) 20736 (52.4
     1975    ---- = 4.36 feet, nearly.—Ans.
     ----     12
      986
      790
     ----
     1960
     ----
```

*Example* 3.—A half-inch plank of larch, similar to our third specimen, being ten feet in length; how many inches will the centre descend before it fractures?

```
 518  tabular value of U.
  .5  depth.
-----
259.0          10 feet = 120.
                 120² = 14400.
             259) 14400 (55.5 inches, nearly.
                  1295
                  ----
                   1450
                   1295
                   ----
                    1550
                    1295
                    ----
                     255
                    ----
```

*Note* 1.—The same rule applies to beams or rods fixed at both ends.

*Note* 2.—According to this rule, our deflection may exceed half the length of the piece. When this takes place, it shows that the ends may be brought together, with a fracture taking place in the beam.

*Note* 3.—When a piece is fixed at one end only, the deflection will be eight times what is given by the rule.

### PROBLEM 6.

To find the ultimate transverse strength of any rectangular beam of timber, fixed at one end, and loaded at the other.

Rule.—Compute the ultimate deflection by Note 3, last Problem; divide this deflection by the length, which will give the sine of the angle of deflection; whence, by a table, find its secant.

Multiply this secant by the breadth and square of the depth in inches, and the product again by the value of S′, in the table of data.

Divide this last product by the length in inches, and the quotient will be the answer in lbs.

### EXAMPLES.

*Example* 1.—What weight will it require to break a piece of fir from the forest of Mar, fixed by one end in a wall, and loaded at the other; the breadth being two inches, depth three inches, and length four feet?

The third Note to the last Problem gives the ultimate deflection, fifteen inches.

Therefore, $\frac{15}{48} = .3125 =$ sine $18° 13'$.

```
The secant of which is....1.0527
                            18 = 2 × 3²
                          ------
                           84216
                          10527
                          ------
                          189486
Value of S′ in tab. =       1310
                         -------
                         1894860
                        568458
                       189486
                       ---------
                   48) 24822,6660 (517 lbs.—Ans.
                       240
                       ---
                         82
                         48
                        ---
                        342
                        336
                        ---
```

*Example* 2.—A square oaken plank of twelve inches the side, projecting eight feet four inches from a solid wall, in which it is fixed; what weight will be required to break it?

The deflection before fracture is 15.325 inches, therefore

$$\frac{15.325}{100}=.15325=\text{sine } 8^\circ\,49',\text{ the secant of which is } 1.0119;$$

$$\frac{1.0119\times 12^3\times 1736}{100}=30345\text{ lbs. nearly.}$$

*Note.*—When the beam is loaded uniformly throughout its length, the last result must be doubled.

### PROBLEM 7.

To compute the ultimate transverse strength of any rectangular beam, when supported at both ends, and loaded in the middle.

RULE.—Multiply the tabular value of S′ by four times the breadth and square of the depth in inches, and divide that product by the length, also in inches, for the weight.

#### EXAMPLES.

What weight will be necessary to break a piece of larch, similar to our third specimen, the length being eight feet four inches, the breadth eight, and depth ten inches, being supported at each end, and loaded in the middle?

Here, tabular value of S′ is 1262

$$\begin{array}{rl}
 & 1262 \\
 & 3200 = 4\times 8\times 10^2 \\
\hline
 & 252400 \\
 & 3786\phantom{00} \\
\hline
8\,ft.\ 4\,in. = 100) & 40384{,}00 \\
\hline
 & 40384\ \text{lbs.—}Ans.
\end{array}$$

*Note* 1.—If the beam be loaded uniformly throughout its length, the result must be doubled.

*Note* 2.—If the beam be fixed at each end, and loaded in the middle, then the result obtained by the rule must be increased by its half.

*Note* 3.—If the beam be fixed at both ends, and loaded uniformly throughout its length, the same result must be multiplied by three.

## III.—ON SCARFING AND LENGTHENING BEAMS.

When timber cannot be procured of sufficient length to answer a required purpose, it becomes necessary to join two or more pieces together, in order to obtain the extent required, and the mode of uniting the pieces is called *Scarfing*.

Scarfing is, therefore, the art of connecting two pieces of timber together, in such manner as to appear like one piece, and possess sufficient strength to answer the purpose which renders this connection necessary.

In scarfing timber it is not requisite to pay particular attention to the form of the joint, as that can be altered at pleasure, to meet the views of the mechanic.

In each piece of timber to be joined, the parts of the joints that come in contact are called *scarfs*.

Scarfs are formed either by a slanting joint, or by notching the two parts together; and, sometimes, by a third short piece, which has a mutual connection with the two.

The projecting parts on each piece are called *tables*.

When the tables are brought in contact, they are firmly secured in that position by bolts passing through the joints.

Some of the most useful methods of scarfing beams will be understood by a reference to the *plate* LXXI.

*Figure* 1, on this plate, shows the method of lengthening beams, without shortening the pieces, by applying an intermediate piece, and connecting the three by means of *steps*.

# SCARFING OF TIMBER.

Fig 1

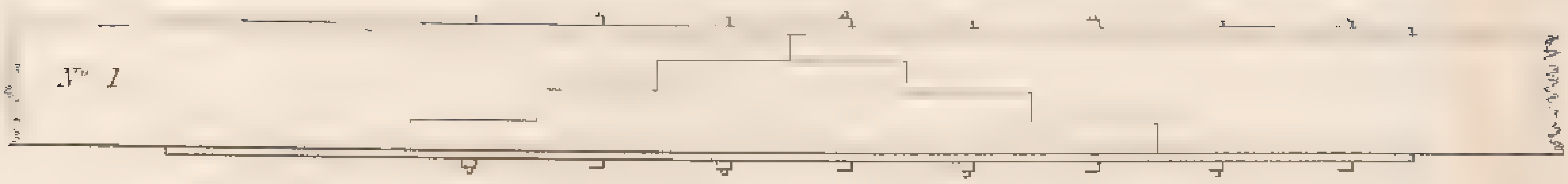



Fig 2

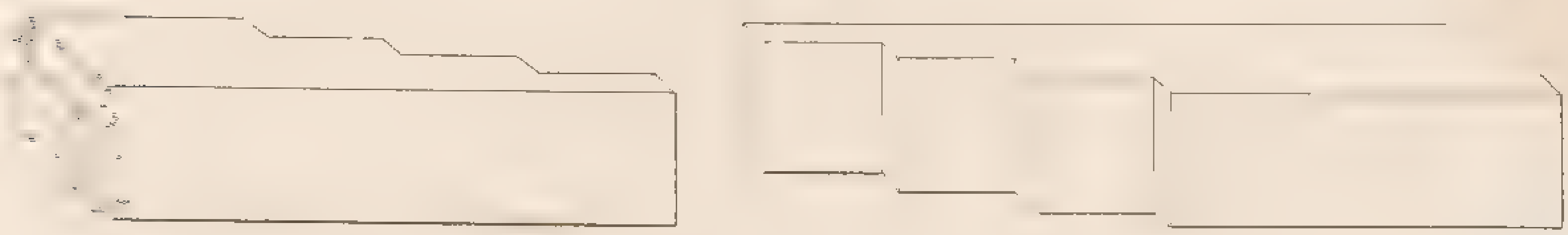


Fig 3

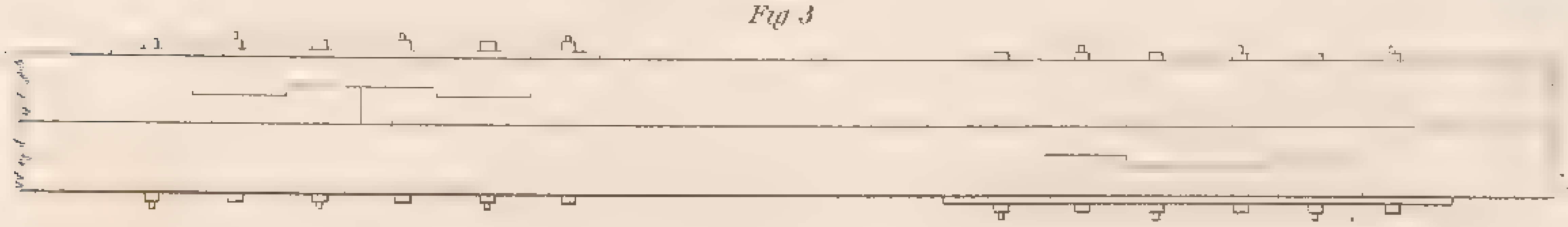


Fig 4

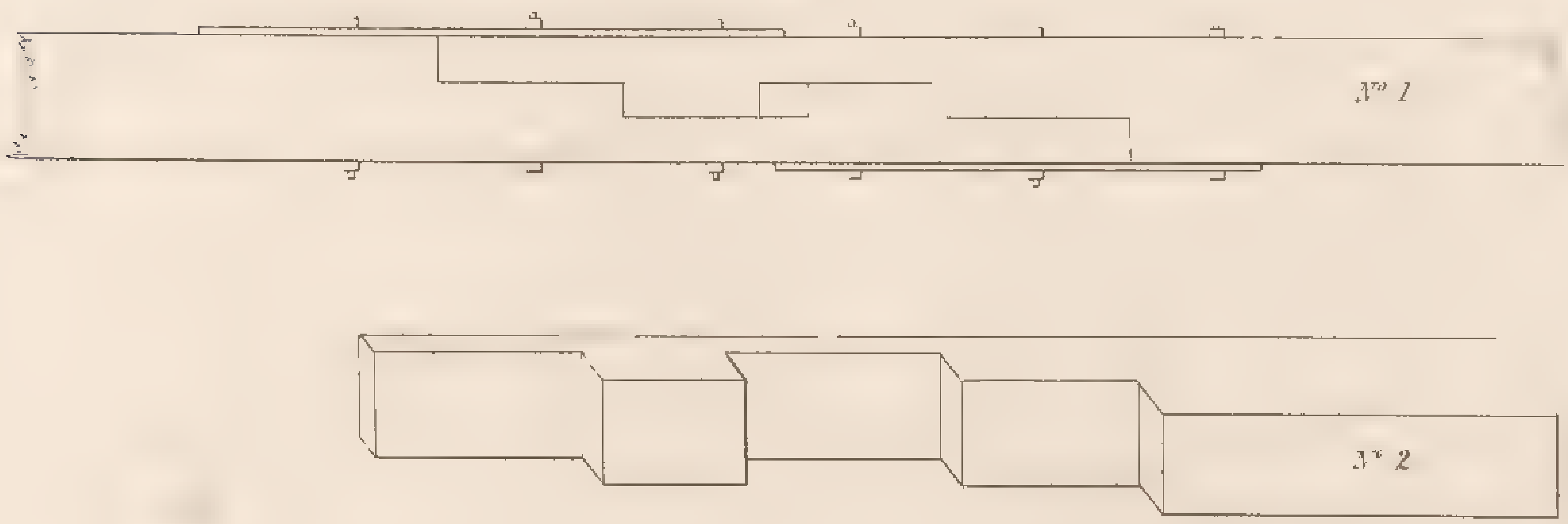
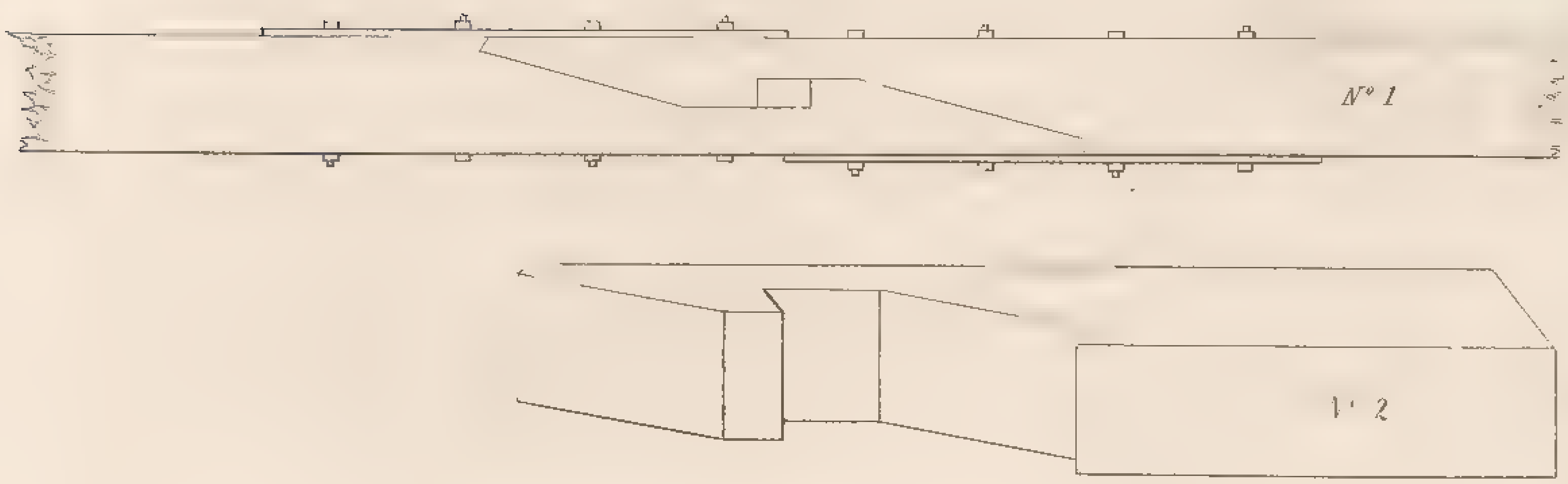



Fig 5




London Published by Thos Kelly 17 Paternoster Row July. 31. 1824.

*Figure* 2 represents a method of joining beams by steps. This method, as well as all that follow, shortens the beam by the entire length of the scarf.

*Figure* 3 is a method of building beams in halves, and locking the two ends that meet each other, by means of a tabulated clamp, indented into the end of each piece.

*Figure* 4 exhibits a method of extending beams by means of indentations, the two parts being locked together by a key or wedge, driven into a mortise left in the middle between the abuting parts of each piece. No. 2 is a perspective view of the scarf and tables, on one of the pieces.

*Figure* 5 exhibits the junction of two pieces of timber by means of an oblique scarf, which is shown distinctly, at No. 2, by a perspective delineation.

The whole of these scarfings should be firmly bolted together, with bolts passing alternately from one side to the other; and, when tabulated, the bolts should be put in the middle of the tables.

## IV.—CENTRINGS, OR CENTERINGS FOR BRIDGES.

In carpentry, a centre means a combination of timber-beams, so disposed as to form a frame, the convex side of which, when boarded over, corresponds to the intended concavity of an arch.

Having carried the piers or abutments to the height designed for the arch to spring, the next object is to set up the centre, the proper construction and erection of which may well be considered as the most masterly operation in the building of arches.

In constructing the centre for an arch, the principal object to be kept in view is, to fix the beams in such a manner as to support (without changing

shape) the weight of the stones and other materials that are to come upon them, through the whole progress of the work, from the springing of the arch to the fixing of the key-stone. This object has not always been sufficiently attended to by the architects of foreign countries; for, in many instances, it has been known that the centres of bridges, from the injudicious principles of their construction, have changed their shape considerably; and, in consequence, the arches built upon them have varied both in form and strength from the intention of the engineer. In Britain, however, no great inconvenience has ever been known to arise from this circumstance; our engineers having constructed their centres on principles calculated to support every weight, and resist every strain to which they might be exposed, and hence have arisen the most perfect models of masonic art that ever marked the progress of human industry.

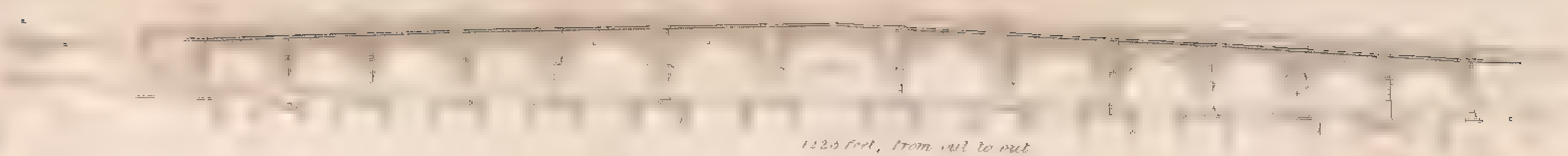
## DESCRIPTION OF PLATE LXXII.

*Figure* 1 shows the centre of Westminster Bridge, which is partly supported by pieces strutting from the footings, and partly by piles driven into the bed of the river.

*Figure* 2, the centre of Blackfriars' Bridge, supported entirely by pieces strutting from the footings and pier.

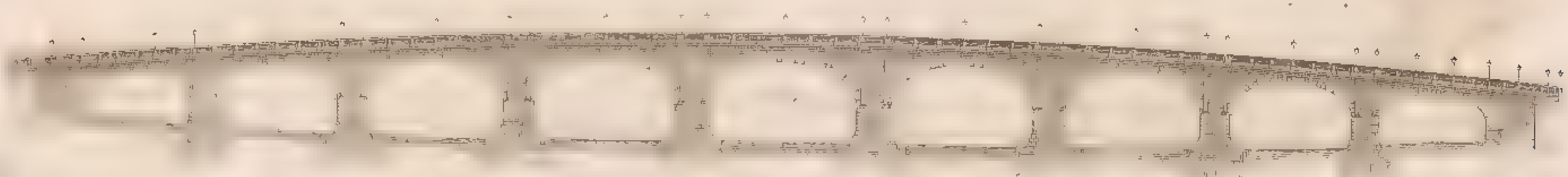
*Figure* 3, a longitudinal section of an arch of Waterloo Bridge, showing the piles on which the piers are raised, the masses of bricks composing the spandrels, and the centre supporting the arch. The dotted line shows the direction of a curve in which the weight is so distributed, that the different pressures to which the edifice is exposed have no tendency to change the form of the arch; and this curve, from the property just mentioned, has received the appellation of the *curve of equilibrium.*

WESTMINSTER BRIDGE



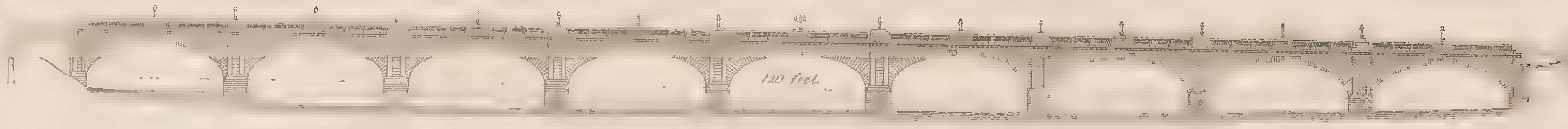
1223 feet, from out to out

BLACKFRIARS BRIDGE.



[illegible] feet, from out to out

WATERLOO BRIDGE.




[illegible] feet from out to out

References

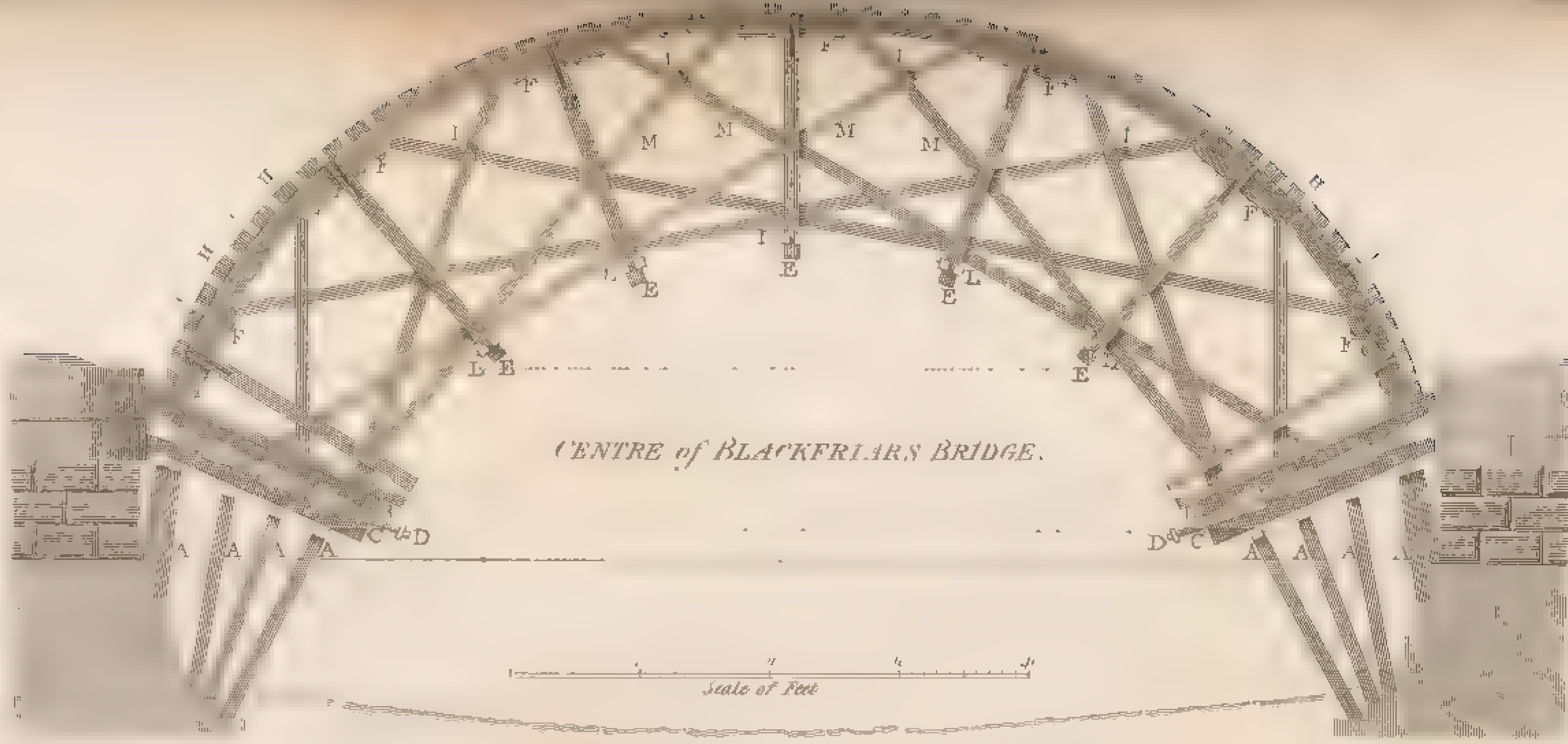
AAAA *Braces which support the centre*

BB CC *Upper and Lower Striking Plates and the wedges*

DD *Wedges between the striking Plates for lowering the centre*

EEEE *Double trussing pieces to connect the Braces*

FFFF *Apron pieces to strengthen the ribs of the centre*




CENTRE of BLACKFRIARS BRIDGE.

GGGG *Bridgings laid on the back of the ribs*

HHHH *Blocks between Bridgings to keep them at equal distances.*

IIII *Small braces to confine them tight*

KKKK *Iron straps bolted to trussing pieces and apron pieces*

LLLL *Ends of beam at the feet of the truss pieces*

MMMM *Principal braces*

SECTION of an ARCH of WATERLOO BRIDGE with the CENTRE.


*Engraved by R. Roffe*

*London, Published by Thos. Kelly 17 Paternoster Row, Aug. 1824*

## WOODEN BRIDGES.

Fig. 1.

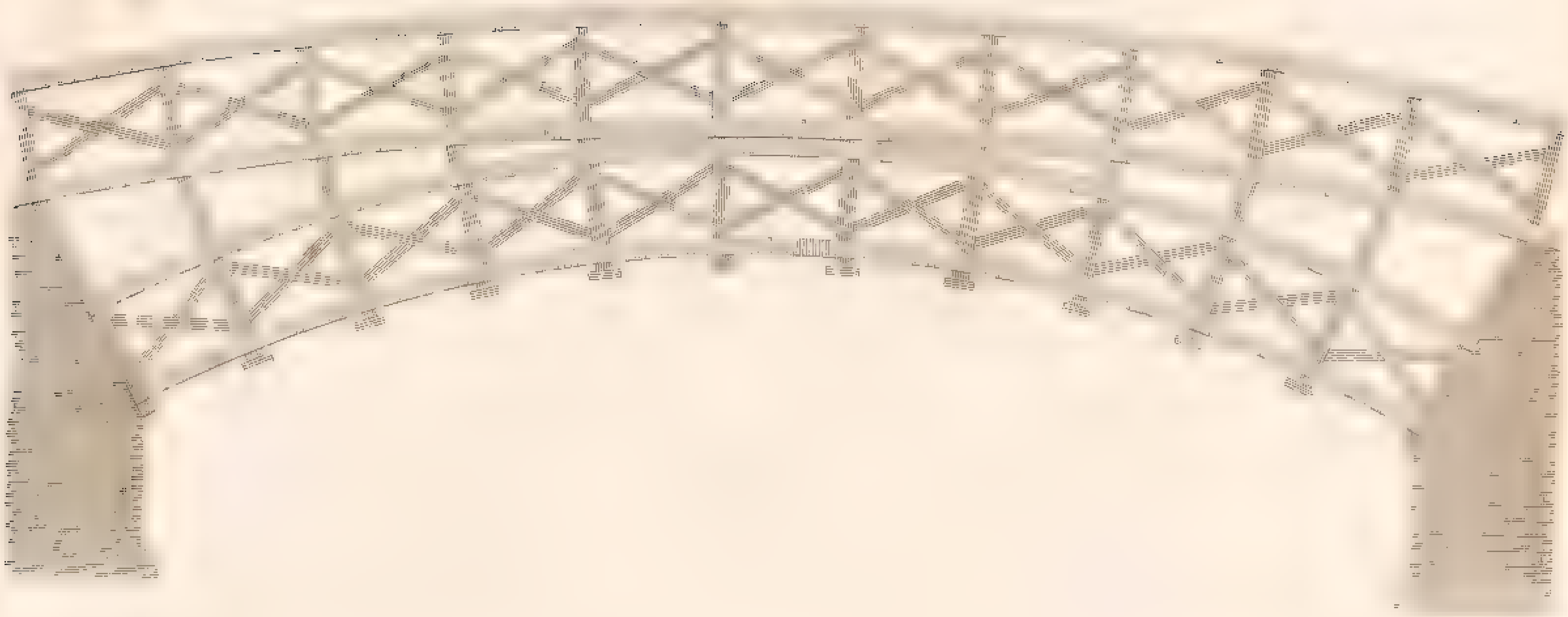


Fig. 2.

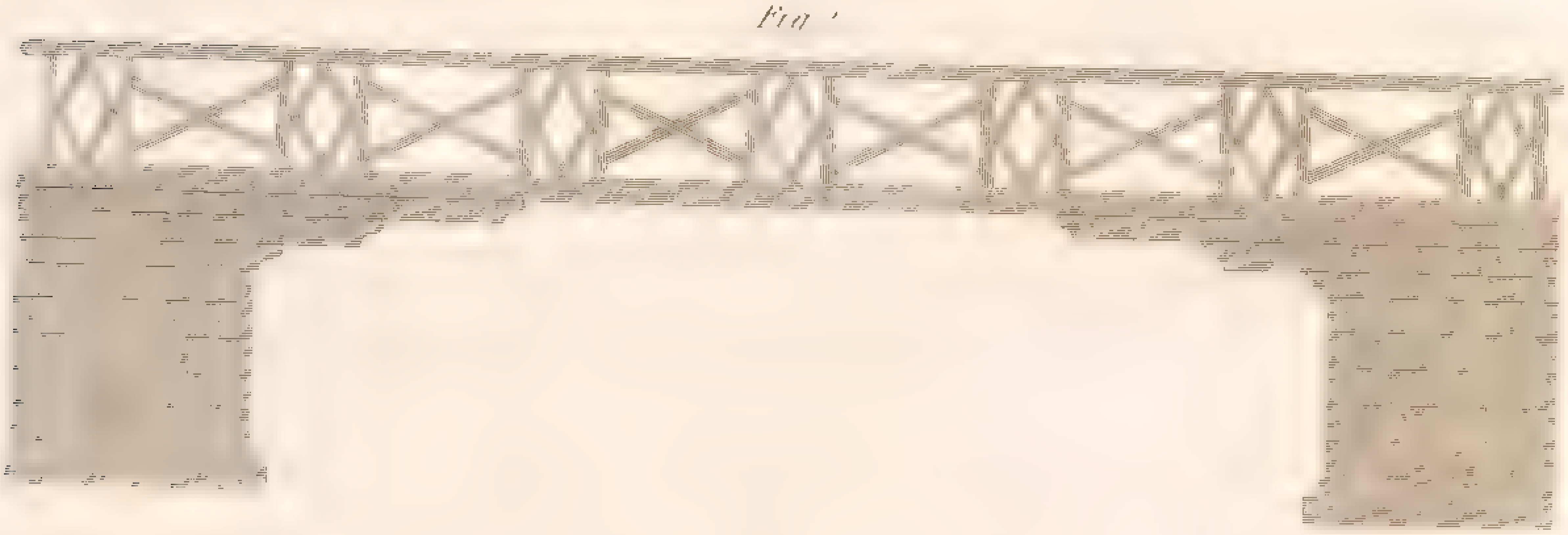


Fig. 3.

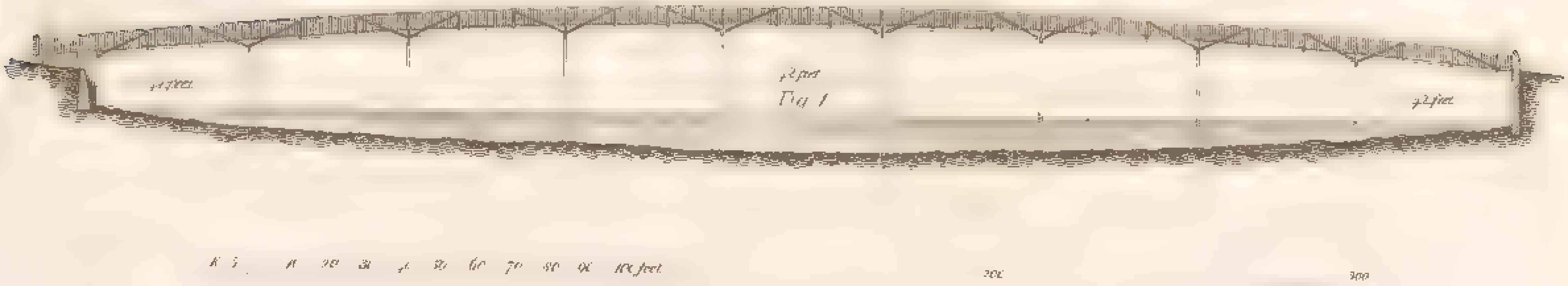
*Drawn by W. Turnbull.*

*Engraved by R.R.*

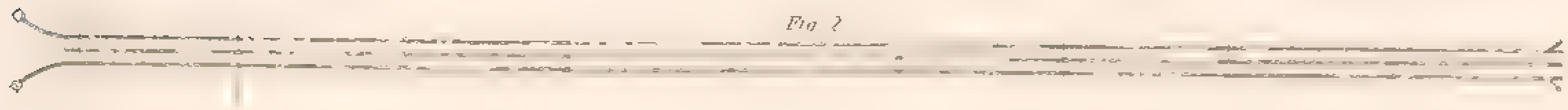
# TIMBER BRIDGE,

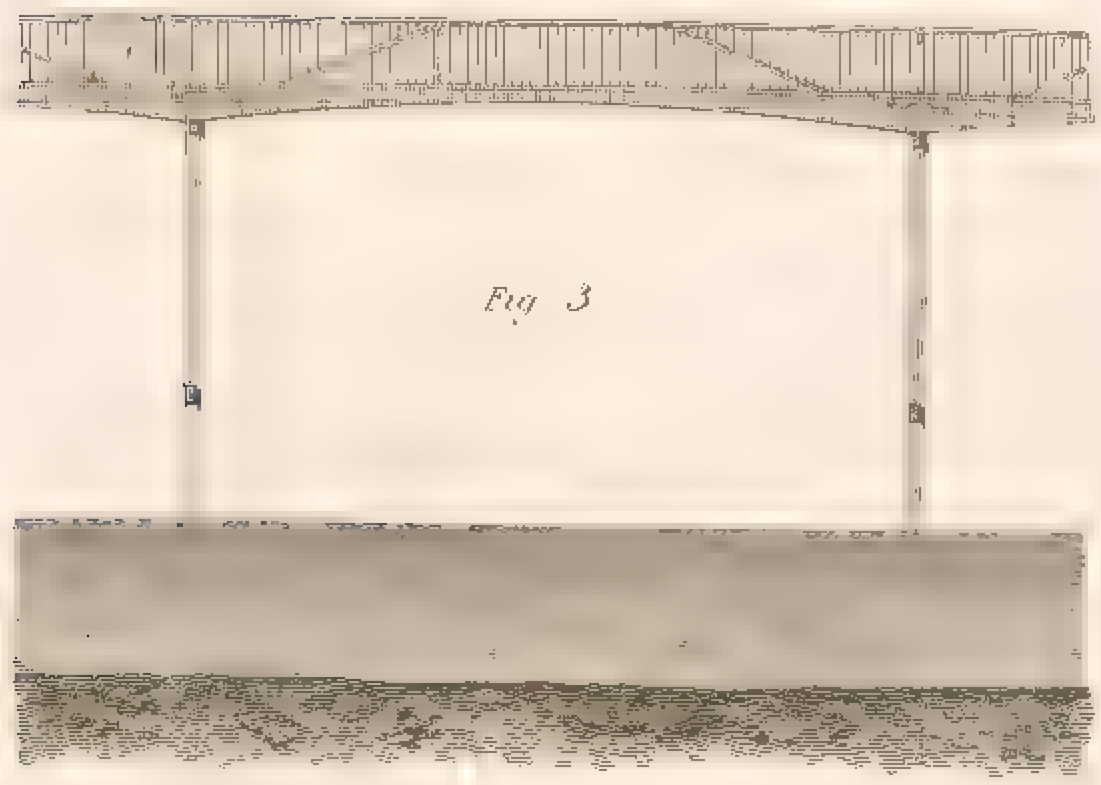
*across the Clyde at Glasgow, superintended by Mr. Nicholson.*

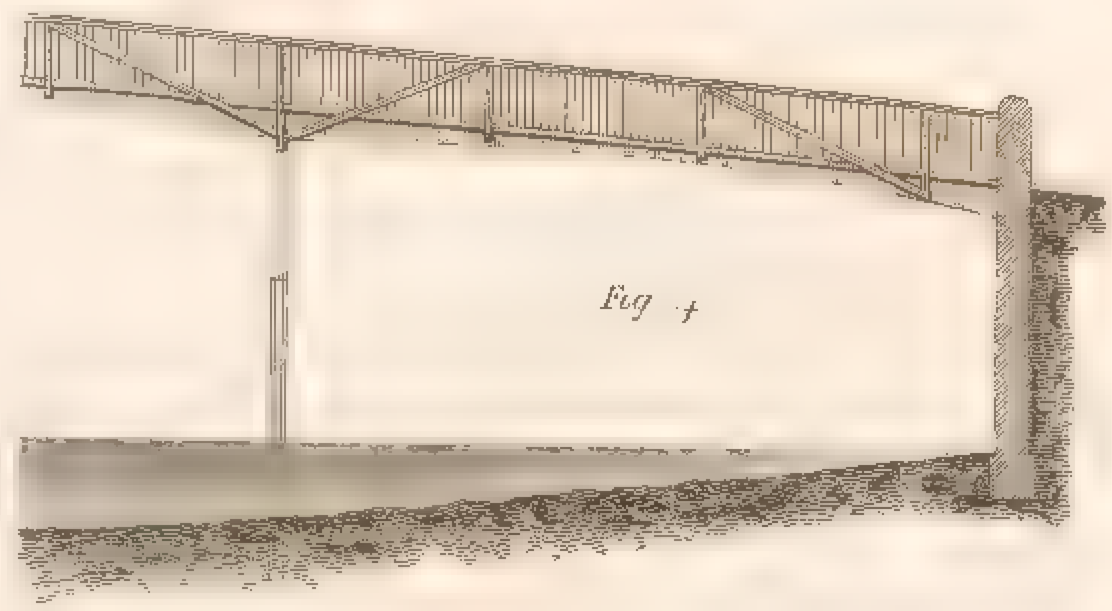
ELEVATION

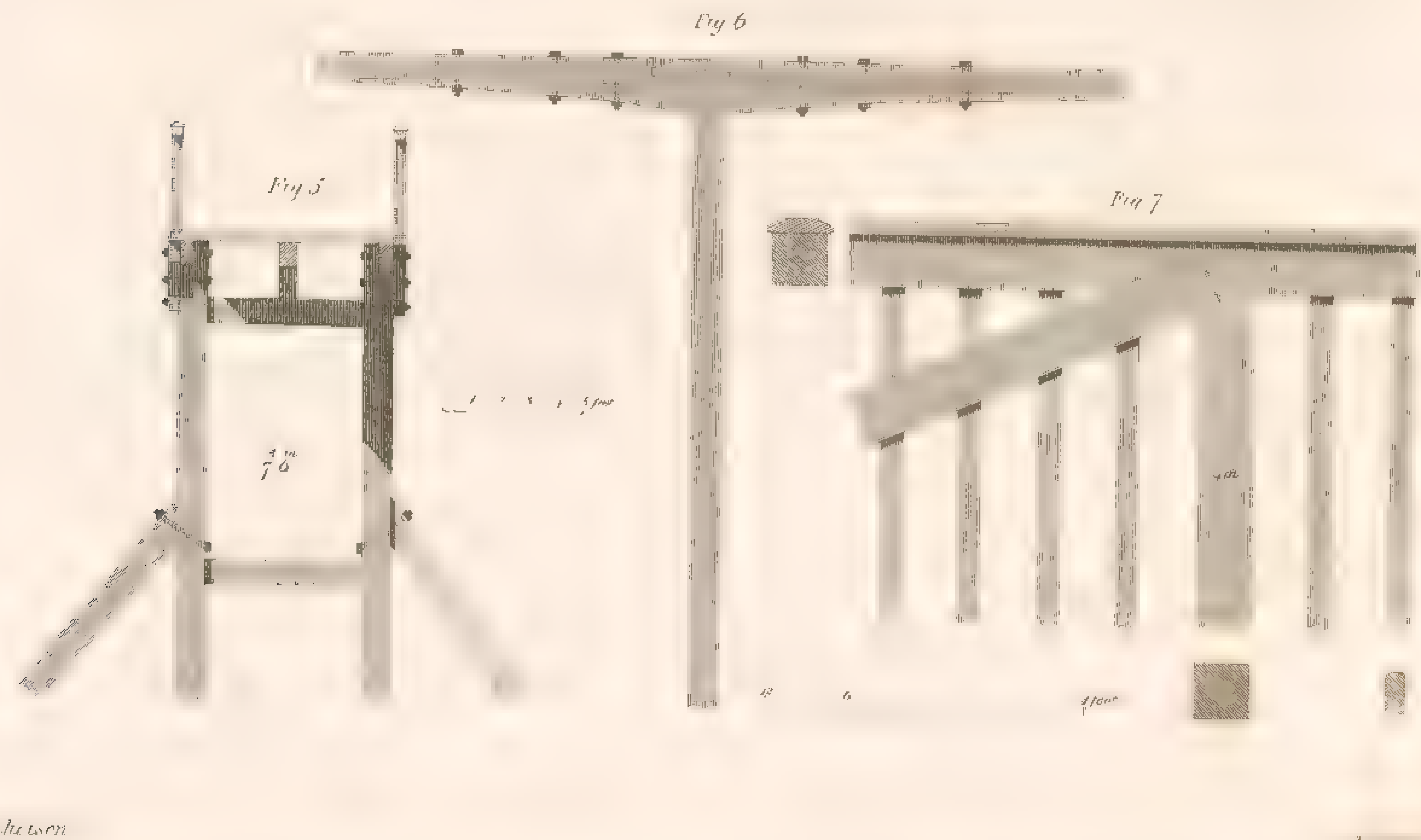


PLAN









Drawn by M. A. Nicholson

Engraved by H. [illegible]

London Published by Thos. Kelly 17 Paternoster Row [illegible] 1823

## V.—CONSTRUCTION OF WOODEN BRIDGES.—(*Pl.* LXXIII.)

*Figure* 1 is the elevation of a wooden bridge supported on the principle of an arch, and may be used where the ground rises on one side more than the other. In order that this bridge may be sufficiently strong, and the road or path-way easily surmounted by passengers and carriages; the curvature of the lower or supporting arch is much greater than that above, forming the road or path-way.

*Figure* 2 is a design for a wooden bridge, supported by brackets, projecting more and more as they rise. This design, as well as the following one, is adapted to a straight road or foot-way.

*Figure* 3, design of a bridge, in which the intrados is the arc of a circle; it is supported by wooden beams over the posts, acting as brackets. To prevent the ends of the supporting brackets from coming to a sharp edge, small keys are let in from the underside.

In order that this bridge may be sufficiently strong, when the space between the posts is very great, a truss is placed in the middle, which increases the strength, so that the span may be extended to two, or even three, times the length that it could be without it.

The Timber Foot-Bridge, over the Clyde, at Glasgow, is represented in the plate bearing this title, which may be numbered LXXIV. It was designed and superintended by Mr. Nicholson, in the year 1808.

*Figure* 1 exhibits the elevation of the bridge. The curve of the road-way is the arc of a parabola. The land abutments are strong masses of masonry, to which the timbers of the floor, or foot-way, are well secured, by cramps of iron bolted to the stone-work.

This bridge was constructed with the view of admitting a certain class of vessels to pass under it. Therefore, to keep the opening between the posts clear, the foot-way is suspended by trusses, which also support the rail-way. The breadth of the foot-way is about ten feet.

*Figure* 2 is a plan of the beams.

*Figure* 3, elevation of the middle opening.

*Figure* 4, elevation of the opening adjoining one of the land abutments.

*Figure* 5, a transverse section, showing also the elevation of the posts and braces.

*Figure* 6 exhibits the scarfing of the beams, the manner of bolting them together, and their junction with the post by which they are supported.

*Figure* 7 exhibits the manner of joining the braces and posts in the rail-way.

This bridge has resisted the most tremendous ice-floods. Floods that have risen to such a height, as only to leave a small part in the middle of the road-way dry. Both Mr. Rennie and Mr. Telford, the most eminent engineers in the country, have given their approbation of its construction, with regard to the intention, its simplicity, and strength.

# CHAPTER VI.

## MASONRY.

MASONRY, practically considered, is the art of shaping and uniting stones for the various purposes of building. It, therefore, includes the hewing of stones into the various forms required, and the union of them, either by joints, level, perpendicular, or otherwise; or by the aid of cement, or of iron, lead, &c. The operations of masonry require much practical dexterity, with some skill in geometry and mechanics.

In treating on this subject, it will be necessary to divide it into several branches, and first we shall notice that local necessity was its parent, and that the fluctuations of the art have always marked the rise and fall of empires.

In Egypt, Greece, and Italy, the greater works of masonry included some which were almost incredible in their extent; and their materials were equally so, if considered in detail. These countries seem to have been favoured in every way, in order to be eternized; for they abounded in porphyries and marbles, which promoted magnificence in their structures, without peculiar contrivance in arrangement. Modern masonry consists rather in the piling stones to a great height, than in covering an extent of plan; but this requires equal skill, if it be not productive of equal magnificence.

## I.—OF THE MATERIALS EMPLOYED IN MASONRY.

Masonry, at the present time, and particularly in Great Britain, is confined more to working in free-stone than in marble; in the former of which our islands greatly abound. The nature or quality of this stone yields with facility to the artificial reduction of it to any required shape. Near Bath, and in several western counties of England, it is sawed into scantlings, by means of a toothed saw; it is afterwards cut with a hand-saw, hewn by an axe, and dragged and smoothed according to the work it is intended for.

Portland free-stone, the most general kind made use of by the London masons, is brought from the Isle of Portland, on the coast of Dorset, in blocks of all dimensions. Its hardness gives it many requisites for producing exquisite masonry. Most of our public buildings are composed entirely of this stone; and it is frequently made use of in dwelling-houses for kirbs, strings, fascias, columns, cornices, floors of halls, vestibules, stair-cases, &c. The Portland free-stone is decidedly the most handsome free-stone known, being capable of bearing an arris in moulding equal to marble; but the great expense of its freight and duty, has lately made the Gloucestershire stone its competitor; and it will, perhaps, in a few years, be entirely superseded thereby, except for internal work, where its superior neatness will always gain it the preference.

The Granites of Cornwall, and the Dundee and Aberdeen stone, are much employed for works requiring great strength and solidity; as for docks, bridges, &c. These stones are so remarkable for their excessive hardness, that it has been found necessary to bring workmen with the stone to London, as few native masons would undertake to work it. The superior strength and durability of this stone over free-stone, will give masons an opportunity, by judiciously blending and arranging the several qualities of stones, to their various purposes, of producing works far more durable than their former materials gave them the power of doing.

Sand-Stone is also common to most counties of England, as well as Scotland. The quarries of sand-stone about the cities of Glasgow and Edinburgh are, however, not equalled in the kingdom; this is evinced by the elegance of the buildings in these places, the superiority of which is to be found in material only, as the taste with which some towns built of brick have been laid out and executed, is not inferior to that displayed by the architects of the north.

In the parish of Sproustone, near Kelso, is a sand-stone quarry, belonging to the Dowager Duchess of Roxburgh, of immense value. The stone is of a beautiful silver grey, but does not, when exposed to the weather, retain its colour, soon becoming of a smokey hue. It is remarkably fine, indeed, so fine, that it is unfit for the purpose of whetting an edged instrument. Most part of Kelso, as well as the whole of the bridges in its vicinity, is built of it. Although not a hard stone, it is very durable, and the seam is so deep and long that stones of any dimensions whatever can be procured from it. This stone has not been much used for a number of years, as some misunderstanding has subsisted between the noble doweress and the present proprietors, respecting the proper right to the use of the mine. It is hoped, however, that the contest will soon cease, and the adjacent country again have the use of a material which conduces so greatly to its neatness and elegance.

There are many excellent beds of sand-stone in the course of the Tweed, but that which we have just mentioned is perhaps the best. A little farther up, on the lands of Dryburgh, the property of the Earl of Buchan, there is plenty of sand-stone, but it is of a deep red colour, and much indented by cross scars and seams; it is not, therefore, so generally useful as some other at no great distance from it. In the body of this stone there are many small pieces of a softer texture, and a deeper red, that do much injury to it as a durable material. The celebrated statue of Sir William Wallace, the defender of Scotish liberty, is cut out of a mass of this stone; but the sculptor, Mr. John Smith, of Darnick, has shown his skill in selecting the piece which he has used, as it appears too hard to yield at all to the ravages of time and of weather.

On the banks of the Tiviot, in the parish of Roxburgh, there is a bed of sand-stone, of excellent quality, fit for almost any purpose to which it may be applied. This has been used to a great extent, by the proprietor, Sir George Douglas, of Springwood Park, but has not been brought into general use. It is of a white yellow colour, and rises from the bed in masses sufficiently large for every purpose of masonry.

In the old buildings, in this neighbourhood, there is a species of sand-stone of a beautiful yellow and uncommonly soft; but where the builders found it cannot now be ascertained, as no vestige of a seam remains wherein the stone is of such a deep and beautiful colour. Should such be discovered, it will be of immense value to the proprietor, as its beauty would bring plenty of purchasers: for, although the fragments that now remain in the old buildings are soft and easily calcined, yet we are not to suppose that it is naturally so; and must rather conclude that it is of a nature not adapted to resist the weather, and that, in process of time, by being exposed to wetness and drought, it becomes of that softness which we have described. A little farther up, on the precipitous banks of the Tiviot, there are extensive beds of this stone; but, from their situation, they cannot be wrought with success.

In Dumfriesshire are great quarries of sand-stone, both of a red and white colour, exceedingly good; but the towns of Dumfries and Maxwelton are mostly composed of the red kind. The masses here are very small, and prevent the mason's exhibiting their skill, to any great extent, in the cutting of figures, and other ornaments of architecture.

If we mistake not, there are numerous and excellent beds of this stone about the town of Kirkcudbright, and the surrounding country: but that which is found abundantly in Ayrshire, on account of its white colour and durable nature, is to be preferred to any that we have yet mentioned, Sproustone only excepted.

The mines in the other parts of Scotland, being nearly of the same nature with those already described, and this remark applying also to the mines of this sort of stone in England, we need not take any farther notice of it; since

its utility, as a building material, is too well known by almost every person to require further detail.

The next sort of stone we shall mention is the COMMON WHIN-STONE, which is so well known to almost every individual as to need no description; but, since we are passing our opinion on stone, we shall say a few words of this also. It is common to almost every country where stone is to be found, but in no place is it so plentiful as in the Highlands of Scotland; and the best for the purpose of the architect is that which is to be found in the beds of rivers, and places adjacent thereto. When broken, it is generally of a blue colour, of close grit, and remarkably hard; but there are species of it subject to rot, and to be otherwise injured by exposure to the weather. Almost all rocks are composed of this stone, from which it rises in great masses, too clumsy and too hard for the polishing influence of the mason's steel.

This stone is excellent in buildings, and many of the best houses in Scotland are composed of no other material: it gathers a sort of coat when it has been long exposed to alternate wetness and drought; this coat is of a grey colour, and tends to bring on a decay of the stone, the durability of which may be considerably increased by frequently cleaning, which is practicable in gentlemen's houses, and the like.

In Scotland, whole towns are built of whin-stone, and this even when a good access to the best of free-stone can be had. This is shown in villages around Kelso, and at Sproustone, in the county of Roxburgh, where, as we have already shown, the best sand-stone in the kingdom is to be found.

## II.—THE CONSTRUCTION OF BRIDGES.

MATHEMATICAL SCIENCE, in all its dignity, is exercised in the theory and construction of bridges. To the enlightened mechanical mind, this, therefore, has always been a favourite subject. To him especially who delights in ranging the field of geometry and the mazes of analysis, and who feels, as he

contemplates them, that enthusiastic emotion which poets and philosophers alone can know.

There are few operations of art to which the man of science can apply his speculative principles so successfully as to the building of bridges; theory, however, has not always kept pace with practice, but now we are flushed with hopes, arising from recent examples, that science will hereafter have a potent influence in directing the operations of the mechanic, and that the carpenter and builder will lean, with full confidence, on the deductions of the mathematician.

The construction of bridges is a subject in itself highly interesting; the hazard attending their erection, and the ingenuity displayed, have such power over a contemplative mind, as to involve it in extreme astonishment. What, indeed, can be more striking than to see a huge mass of ponderous stones, suspended, not only over small brooks and rivulets, but over the mightiest rivers in the world? Yea, so far has the intrepidity of the engineer carried him, as to attempt throwing bridges even over arms of the sea; and here, also, has success been complete. Another source of astonishment is the neatness and elegance of the structure itself. Holding at nought the danger attending their labour, the workmen must show their skill in preparing, placing, and embellishing, their materials, as if ornament, more than utility, were the object of their wishes: but, generally, it will be found that, while ornament is obtained, utility is not overlooked; for the stones are so artfully constructed and laid together, that, in combination, they give mutual support, and the heaviest load can be carried over with perfect safety.

The construction of a perfect bridge is, however, a very complex operation; it could not be accomplished by a rude and unintelligent people; and we find, in the history of bridges, that the erection of arches did not always correspond with the progress of other arts, even where an advantageous intercourse subsisted.

The SIMPLEST BRIDGE is obviously that which is composed of a single tree, thrown across a small stream, whose width is not too great for the length of the tree: but, when this is the case, a higher effort of inventive power is

necessary, and this is also soon supplied by stretching another tree from the opposite side, and fastening them together in the middle, by some means or other, such as twisting the branches. This sort of bridge must frequently occur by chance. Mr. Park found such in the interior of Africa.

The next step is not much more complex; for the process of twining ropes of rushes or leathern thongs is very simple; and, when the stream is too wide for one length, we have only to stretch as many as may be necessary, from one tree to another, on the opposite banks of the stream, and cover them so as to answer the purpose required. Bridges of this kind have been constructed in South-America.

The next mode of forming bridges is to construct piers of stone, at such a distance from each other, as to admit a beam of timber, or a long single stone, to stretch over the width of the stream. This, if the water be shallow, is a very simple operation; for the piers may be built of rough stone without mortar, and such a process would soon present itself to a rude people.

But, if the stream be at all times rapid and deep, and the piers built of hewn stone laid with mortar, we may infer that the people who formed such a structure are a people acquainted with the useful arts; for it is clear that the stones must previously have been quarried and hewn, and before a proper foundation for the pier could be had, the union and experience of various arts were required: hence, then, we conclude that the society in which a work of this sort, of any considerable magnitude, is accomplished, is far advanced in civilization, and has the command of much well-regulated labour.

With respect to the mode, now commonly adopted, of constructing arches between piers of stone, the history of the Chinese leads us to understand, that they erected bridges in this manner many centuries before arches were known in Europe, or to the inhabitants of any part of the western world: but, when we consider the many specious claims that this empire has held forth for the high antiquity of its improvements and inventions, we may perhaps feel but little disposed to credit the assertion. Certain, however, we are, that arches are numerous as connected with their inland navigation.

In Egypt and in India, the gardens which have produced many useful inventions, both in science and in art, the construction of the arch was totally unknown; for the temples of the one, and the tombs of the other, were produced by cutting matter away in the manner of sculpture: and further, in the antient works of Persia and Phœnicia no trace of an arch can be found. The Greeks created a school of architecture and sculpture, and carried their knowledge very far in these departments, yet even they have but an obscure claim to the knowledge of the arch. It is, at least, certain that they never used it externally in their temples, much less in the construction of bridges.

It is to the Romans, then, that we are indebted for this useful application of a great principle in architecture; but there is no certainty as to the time when it was first practised. It is asserted, by some, that the Romans derived their knowledge of the arch from the Tuscans; but, if this were admitted, the first knowledge of the art is at least very intimately connected with Greece, for we believe it is not disputed that the Tuscans were a colony of Dorians.

But, however doubtful may be the claim to the invention of the arch, we know, from history, that the Romans were the first to apply it to useful purposes; such as forming aqueducts for conveying water to cities, erecting bridges over rivers, vaulting temples, and the like, and in erecting monuments to record the exploits of their heroes.

Having thus touched on the rude bridges of uncivilized nations, and shown that the Romans were the first to bring the arch into general use, we shall pass over the description of the massy structures of this kind that have been reared in other countries, and confine ourselves to those only which are conspicuous in our own kingdom, beginning with the BRIDGE of LONDON.

This bridge was originally begun in the year 1176, by a priest, called Peter, curate of St. Mary Colechurch, a celebrated architect of those times, and occupied thirty-three years in building; but this period will not appear surprising, when it is considered that it was built over a river in which the tide rises, twice every day, from 13 to 18 feet. The bridge at first consisted

of twenty arches, but, in 1758, the middle pier was taken down, and the two adjacent arches were converted into one, the span of which is seventy-two feet; its breadth is forty-five feet, and for many ages there were houses along each side of it, but these were removed, when the middle pier was taken down, in 1758. The remaining arches are very narrow, and the piers inconveniently large, being from fifteen to twenty-five feet in thickness. The passage over the bridge is very commodious, but in other respects there is nothing remarkable about it.

The foundation-stone of WESTMINSTER BRIDGE was laid by the Earl of Pembroke, (a nobleman distinguished by his taste in architecture,) on the 24th January, 1739. It consists of thirteen large and two small semi-circular arches, of which the middle one is seventy-six feet span, and the parapets forty-four feet. The engineer was M. Labelye, a native of France; but a Mr. James King, it is believed, had some hand in the design of it.

About ten years after this magnificent edifice was completed, another was begun, at a mile lower down the river, known by the name of BLACKFRIARS'; the design was by Mr. Robert Mylne: it consists of nine arches, of an elliptical form, of which the middle one is one hundred feet in span, and the breadth across the bridge is forty-three feet six inches. The arches being elliptical, and of wider span than those of Westminster, the bridge, of course, has a lighter appearance. The general stile of it bespeaks a mind emboldened by the success of his predecessors, to advance a cautious step in the practice of bridge-building. It is a work of very great merit, and will stand a comparison with any other constructed in the same age. It was finished in $10\frac{3}{4}$ years.

But the glory of England, in bridge-building, may be seen in the Strand or Waterloo Bridge, recently erected by Mr. Rennie, between Westminster and Blackfriars' Bridges; and in the Southwark Bridge, between London and Blackfriars' Bridges. Many other excellent bridges have also been constructed in Britain, both of wood, iron, and stone, but to enter into a full detail of them here, would swell this article far beyond our prescribed bounds; we must, therefore, drop this interesting subject, and proceed to give a slight sketch of the *theory*, as connected with the principles of Mechanical Philosophy.

In the THEORY of BRIDGES we have first to examine the nature of *equilibration;* as, by a proper knowledge of, and attention to, this important subject, the beauty and stability of bridges are to be secured.

The celebrated Dr. Hook proposed, as a proper form for an arch, the curve into which a rope or chain would arrange itself, if suspended at the two extremities by pins or nails fixed in a wall; this curve is commonly called the *catenaria,* the properties of which have been investigated by different mathematicians. We do not, however, mean to give a full development of its principles in this place, but confine ourselves to what is necessary for our purpose, in order to understand the equilibrium of an arch.

Let a chain, or string of beads, equal in size and density, be suspended at its extremities by two pins or nails. It will form itself into a curve line. Suppose this curve to be turned steadily round till it obtain a position in the same plane that the beads formed themselves into in the curve; then all the beads in the arch will, by gravity and an equal pressure, retain the same position; and, consequently, the arch formed will be the catenaria. This arch, however, would support no weight, a mere breath being sufficient to destroy the equipoise.

But, should we suppose the beads, in place of being small globes or spheres, to become pieces of a cubical form, equal in height to the diameter of the globes, and retaining the same position, the stability of the arch would be more considerable. The arch is now formed of a mass of truncated wedges, arranged in the catenarian curve, which passes through their centres; and from this we infer that, when arches of other forms are supported, it is because some catenaria exists some where in their thickness. If the stones are all of the same weight, and touch only in a single point, this curve is, indeed, the only one proper for arches that have to support themselves without being disturbed by different weights or pressures; but, for arches that, besides the loads continually passing over them, have their haunches filled up, it is not so well adapted till farther modifications take place.

Suppose it were required to determine the form of an arch, of a given span and height, proper to carry a road-way of a given form.

Let the proposed span be marked horizontally, on a vertical plane of any substance that may answer the purpose; bisect the span by a perpendicular directed downwards, and equal to the given height; from the extremities of the span suspend a rope or chain, so that its middle point may be a little below the point marking the intended height of the arch; divide the span into any number of equal parts, and at the points of division raise perpendiculars cutting the suspended chain in particular points; from these points suspend pieces of chain, so adjusted that their ends may meet the line of road-way: and it may be observed that, as those which hang near the haunch bring it down, the crown will rise to its proper position.

If the sum of the small chains has, to the large one suspended from the extremities of the span, the same ratio that the material to be filled into the haunches has to the whole weight of the arch stones, this will be the exact form of the arch required to support the given road-way.

Having given this mechanical method of determining the form of the arch, under the conditions proposed, we shall next show the requisites of the piers to support the arches. And here we must consider, that the piers and abutments of bridges should be so constructed that each arch may stand alone, independently of any other support but its own weight resisted by the piers.

Many writers on the theory of bridges have found it necessary to determine the centre of gravity of the semi-arch, by means of the higher calculus; but we shall here content ourselves with principles of an easier nature, as the deductions will be the more easily applied to practice.

The ultimate pressure of arches may, in all cases, be reduced to two others; viz., the horizontal thrust, and the weight of the semi-arch: but in the arch of equilibration, this pressure is directed perpendicularly to the joints of section, and, when we make an allowance, in other cases, for the effects of friction, the horizontal thrust is not to be feared. Therefore, we have chiefly to attend to the pier itself, taking care to have it of sufficient weight, that it may not overset by turning on its lower point, as a fulcrum. Take a point in the horizontal joint, to represent the centre of pressure, and, at this point, raise a line perpendicularly, to represent the weight of the semi-

arch; at the extremity of this draw another line, perpendicularly, to represent the horizontal thrust, and let the distant extremity of this line be connected with the assumed point; the connecting line will show the ultimate pressure, and if, when produced, this line fall within the base of the pier, it is evident that it cannot overturn it. But, even though the production of this line fall without the base of the pier, the tendency that the pier has to be overturned may be destroyed by its weight; for this weight may be supposed concentrated in the centre of gravity of the pier, and therefore to act in a vertical line bisecting it.

We shall now give analytical expressions for these forces, in order to which, let $t =$ horizontal thrust;

$w =$ weight of the half-arch;

$p =$ weight of the pier;

$h =$ height of the pier to the springing of the arch;

$b =$ the breadth at the base.

Then, $ht = \frac{1}{2} bp + \frac{3}{4} bw$; from which equation any one of the quantities can be expressed in terms of the rest. Thus, suppose it were required to find the breadth of the base of the pier, that is, to express it in terms of the other quantities which enter into its construction.

Recurring to our equation, we have $b\left(\frac{1}{2} p + \frac{3}{4} w\right) = ht$; then, dividing by $\left(\frac{1}{2} p + \frac{3}{4} w\right)$, it becomes $b = \frac{ht}{\frac{1}{2}p + \frac{3}{4}w} = \frac{4ht}{2p + 3w}$.

Again, to find the height of the pier, it is $h = \frac{b(2p+3w)}{4t}$.

To find the weight of the pier, it is $p = \frac{4ht - 3bw}{2b}$.

To find the weight of the half arch, we have $w = \frac{4ht - 2bp}{3b}$.

To find the horizontal thrust, we have $t = \frac{b(2p+3w}{4h}$.

We shall show the numerical application of these formulæ, by assuming numbers to represent the different quantities, without regarding whether they be or be not such as would actually occur in the construction of bridges.

Let $t = 250$

$w = 1000$

$p = 166$

$h = 15$

$b = 4\frac{1}{2}$.

Now, suppose we want to discover the value of $b$; the base of the pier; the formula is $b=\frac{4ht}{2p+3w}$; that is, $b=\frac{4\times 15\times 250}{(2\times 166)+(3\times 1000)}$.

The actual operation is as follows:

$$
\begin{array}{rrr}
166 & 1000 & 250 \\
2 & 3 & 4 \\
\hline
332 & 3000 & 1000 \\
 & 332 & 15 \\
\hline
 & 3332\ ) & 15000\ (\ 4.5=b. \\
 & & 13328 \\
\hline
 & & 16720 \\
 & & 16660 \\
\hline
 & & 60 \\
\hline
\end{array}
$$

To find $h$, the height of the pier, the formula is $h=\frac{b(2p+3w)}{4t}=\frac{4\frac{1}{2}\left((2\times 166)+(3\times 1000)\right)}{4\times 250}$.

$$
\begin{array}{rr}
166 & 1000 \\
2 & 3 \\
\hline
332 & 3000 \\
 & 332 \\
\hline
 & 3332 \\
 & 4\frac{1}{2} \\
\hline
250 & 13328 \\
4 & 1666 \\
\hline
1000\ ) & 14994\ (\ 14.994, \text{ or nearly } 15. \\
 & 1000 \\
\hline
 & 4994 \\
 & 4000 \\
\hline
 & 994 \\
\hline
\end{array}
$$

To find the weight of the pier, the formula is $p=\frac{4ht-3bw}{2b}=\frac{4\times15\times250-3\times4\frac{1}{2}\times1000}{2\times4\frac{1}{2}}$.

```
              250      1000
                4        4½
             -----    -----
             1000      4000
               15       500
             -----    -----
     4½     15000      4500
     2      13500         3
     --     -----    ------
     9 )     1500     13500
            -----    ------
              166 = p.
```

To find the weight of the half arch, the formula is $w=\frac{4ht-2bp}{3b}=\frac{4\times15\times250-2\times4\frac{1}{2}\times166}{3\times4\frac{1}{2}}$.

```
             250              166
               4               4½
           -----            -----
    4½      1000              664
    3         15               84
   ---     -----            -----
   13½     15000              748
    2       1496                2
   ---     -----            -----
   27 )    13504 ( 500       1496
           135       2      -----
           -----   ----
              04   1000 = w.
```

To find the horizontal thrust, the formula is $t=\frac{b(2p+3w)}{4h}=\frac{4\frac{1}{2}(2\times166+3\times1000)}{4\times15}$.

```
   166    1000
     2       3
   ---    ----
   332 + 3000 = 3332
                  4½
                ----
          15   13328
           4    1666
          --   -----
          60 ) 14994 ( 24.99
               120
               ---
                299
                240
                ---
                 594
                 540
                 ---
                  540
                  540
                  ---
```

There are other circumstances which enter into the construction of bridges, that would, if considered, give a change to the general equation which we have used; but as these have been so fully elucidated in other works, written on bridges, it is needless to dwell longer on this subject here: we proceed, therefore, to give a brief view of the fall of water under the arches of a bridge, it being necessary to pay some attention to this, also, in rearing the edifice.

It is known that, if the same quantity of water, that flows in an open extended channel, have to pass through a space any way contracted, it rises above the general level; and, consequently, has the velocity of its current increased. The piers of a bridge form obstacles in the way of running waters, and in proportion as they contract the channel, the water will rise above the usual level, and the rapidity of the current be increased; but the investigation of the law of increase, agreeing to a given contraction, would occupy too much room for our present purpose, and would, also, be too refined a speculation for this work; we shall, therefore, present a table which may be of considerable use to men of practice, as the desiderata is brought at once under his view.

THE RISE *of* WATER *produced by* OBSTRUCTIONS *to the* CURRENT, *as by Square-ended Piers, or abrupt Projections.*

| VELOCITY. | | DESCRIPTION OF RIVERS. | | OBSTRUCTIONS. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $\frac{1}{12}$ | | $\frac{1}{10}$ | | $\frac{1}{8}$ | | $\frac{1}{6}$ | | $\frac{1}{4}$ | |
| Per Second. | Per Hour. | The Current usually termed. | The Bottom which just bears such Velocities. | Head of Water, and Velocity produced at the Obstruction, in Feet. | | | | | | | | | |
| Ft. In. | Miles | | | Head. | Vel | Head. | Vel. | Head. | Vel. | Head | Vel. | Head. | Vel. |
| $\frac{1}{4}$ or 3 | $\frac{1}{6}$ | Dull, | Oaze and Mud, | .0008 | .34 | .0009 | .35 | .0010 | .36 | .0012 | .37 | .0017 | .42 |
| $\frac{1}{2}$ or 6 | $\frac{1}{3}$ | Gliding, | Soft Clay, | .0034 | .68 | .0036 | .69 | .0041 | .73 | .0049 | .75 | .0069 | .83 |
| 1 | $\frac{15}{22}$ or $\frac{2}{3}$ | Smooth, | Sand, | .0134 | 1.36 | .0145 | 1.39 | .0162 | 1.46 | .0197 | 1.5 | .0276 | 1.66 |
| 2 | $1\frac{4}{11}$ | Uniform Tenors, | Gravel, | .0536 | 2.73 | .0580 | 2.68 | .0650 | 2.93 | .0788 | 3. | .1104 | 3.33 |
| 3 | $2\frac{1}{22}$ | Ordinary Freshes, | Pebbles, Shivers, and Shingle, | .1207 | 4.09 | .1305 | 4.06 | .1462 | 4.39 | .1773 | 4.5 | .2484 | 5. |
| 4 | $2\frac{8}{11}$ | | | .2146 | 5.45 | .2320 | 5.45 | .2600 | 5.86 | .3152 | 6. | .4416 | 6.66 |
| 5 | $3\frac{9}{22}$ | Extraordinary Floods and Rapids, | Boulders and Soft Schistus, | .3353 | 6.82 | .3625 | 6.94 | .4062 | 7.32 | .4925 | 7.5 | .6900 | 8.33 |
| 6 | $4\frac{1}{11}$ | | Stratified Rocks, | .4828 | 8.18 | .5320 | 8.33 | .5840 | 8.78 | .7092 | 9. | .9936 | 10. |
| 10 | $6\frac{9}{11}$ | Torrents and Cataracts | Indurated Rocks, | 1.341 | 13.64 | 1.45 | 13.9 | 1.625 | 14.6 | 1.97 | 15. | 2.76 | 16.3 |

*The Rise of Water produced by Obstructions to the Current, &c. continued.*

| VELOCITY. | | DESCRIPTION OF RIVERS. | | OBSTRUCTIONS. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Per Second | Per Hour. | The Current usually termed. | The Bottom which just bears such Velocities. | $\frac{1}{3}$ | | $\frac{1}{2}$ | | $\frac{5}{8}$ | | $\frac{3}{4}$ | | $\frac{7}{8}$ | |
| | | | | Head of Water, and Velocity produced at the Obstruction, in Feet. | | | | | | | | | |
| Ft. In | Miles. | | | Head. | Vel | Head | Vel. | Head. | Vel | Head | Vel. | Head. | Vel |
| $\frac{1}{4}$ or 3 | $\frac{1}{6}$ | Dull, | Oaze and Mud, | .0024 | .468 | .005 | .87 | .010 | .83 | .023 | 1.75 | .096 | 2.5 |
| $\frac{1}{2}$ or 6 | $\frac{1}{3}$ | Gliding, | Soft Clay, | .0098 | .937 | .020 | 1.75 | .039 | 1.66 | .094 | 2.5 | .386 | 5. |
| 1 | $\frac{15}{22}$ or $\frac{2}{3}$ | Smooth, | Sand, | .0393 | 1.875 | .082 | 2.5 | .158 | 3.33 | .375 | 5. | 1.546 | 10. |
| 2 | $1\frac{4}{11}$ | Uniform Tenors, | Gravel, | .1572 | 3.75 | .328 | 5. | .632 | 6.66 | 1.500 | 10. | 6.184 | .. |
| 3 | $2\frac{1}{22}$ | Ordinary Freshes, | Pebbles, Shivers, and Shingle, | .3537 | 5.62 | .738 | 7.5 | 1.422 | 10. | 3.375 | .. | 13.914 | .. |
| 4 | $2\frac{8}{11}$ | | | .6288 | 7.5 | 1,312 | 10. | 2.528 | .. | 6.00 | .. | 25. | .. |
| 5 | $3\frac{9}{22}$ | Extraordinary Floods and Rapids, | Boulders and Soft Schistus, | .9825 | 9.37 | 2.050 | .. | 3.95 | .. | 9.375 | .. | 38. | .. |
| 6 | $4\frac{1}{11}$ | | Stratified Rocks, | 1.4148 | 11.24 | 2.952 | .. | 5.688 | .. | 13.5 | .. | 56. | .. |
| 10 | $6\frac{9}{11}$ | Torrents and Cataracts | .... | 3.930 | .. | 8.20 | .. | 15.8 | .. | 37.5 | .. | .. | .. |

We do not pretend to say, that the table now given is complete, yet, in all probability, it will be found to answer many useful purposes; but, in order that the table might be as perfect as possible, it should be divided into two parts: one referring to the velocity, and the other to the difference of level of the river's surface, for a space equal to the breadth of the bridge. The depth should also be particularly attended to, in discovering the acquired velocity; but we will not enter into these delicate circumstances, as the data cannot always be obtained with similar exactness.

We shall now give an example to show the use of the table.

Suppose it were required to build a bridge over a river, 100 feet wide, and velocity three feet per second; but the abutments and piers together reduce the water-way to 75 feet, that is, diminishing the original width by one-fourth.

Look in the table, opposite to 3 feet, and under the obstruction $\frac{1}{4}$, and .2484 will be the head found; this is about three inches, and therefore is not likely to encroach on the crown.

## THE RISE *of* WATER *produced by* OBSTRUCTIONS *to the* CURRENT, *when formed to diminish Contraction, as Piers, with Pointed Sterlings, &c.*

| VELOCITY. | | DESCRIPTION OF RIVERS. | | OBSTRUCTIONS. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Per Second. | Per Hour. | The Current usually termed. | The Bottom which just bears such Velocities. | $\frac{1}{12}$ | | $\frac{1}{10}$ | | $\frac{1}{8}$ | | $\frac{1}{6}$ | | $\frac{1}{4}$ | |
| | | | | Head of Water, and Velocity produced at the Obstruction, in Feet. | | | | | | | | | |
| Ft. In. | Miles. | | | Head. | Vel. | Head. | Vel. | Head. | Vel. | Head. | Vel. | Head. | Vel. |
| $\frac{1}{4}$ or 3 | $\frac{1}{6}$ | Dull, | Oaze and Mud, | .0003 | .28 | .0004 | .29 | .0004 | .30 | .0006 | .32 | .001 | .35 |
| $\frac{1}{2}$ or 6 | $\frac{1}{3}$ | Gliding, | Soft Clay, | .0011 | .56 | .0014 | .58 | .0017 | .60 | .0023 | .63 | .004 | .70 |
| 1 | $\frac{15}{22}$ or $\frac{2}{3}$ | Smooth, | Sand, | .0045 | 1.13 | .0056 | 1.16 | .0069 | 1.20 | 0091 | 1.26 | .015 | 1.40 |
| 2 | $2\frac{1}{3}$ | Uniform Tenors, | Gravel, | .0182 | 2.27 | .0225 | 2.33 | .0276 | 2.40 | .0364 | 2.52 | .060 | 2.80 |
| 3 | $2\frac{1}{22}$ | Ordinary Freshes, | Pebbles, Shivers, and Shingle, | .0409 | 3.40 | .0507 | 3.39 | .0621 | 3.60 | .0819 | 3.78 | .135 | 4.20 |
| 4 | $2\frac{8}{11}$ | | | .0728 | 4.54 | .0902 | 4.66 | .1104 | 4.80 | .1456 | 5.04 | .240 | 5.60 |
| 5 | $3\frac{9}{22}$ | Extraordinary Floods and Rapids, | Boulders and Soft Schistus, | .1137 | 5.68 | .1410 | 5.83 | .1725 | 6.00 | .2275 | 6 30 | .375 | 7.00 |
| 6 | $4\frac{1}{11}$ | | Stratified Rocks, | .1638 | 6.81 | .2030 | 6.99 | .2484 | 7.20 | .3276 | 7.56 | .540 | 8.40 |
| 10 | $6\frac{9}{11}$ | Torrents and Cataracts | .... | .4550 | 11.36 | .5640 | 11.66 | .6900 | 12.00 | .9100 | 12.60 | 1.500 | 14. |

| VELOCITY | | DESCRIPTION OF RIVERS. | | OBSTRUCTIONS. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Per Second | Per Hour. | The Current usually termed. | The Bottom which just bears such Velocities. | $\frac{1}{3}$ | | $\frac{1}{2}$ | | $\frac{5}{8}$ | | $\frac{3}{4}$ | | $\frac{7}{8}$ | |
| | | | | Head of Water, and Velocity produced at the Obstruction, in Feet. | | | | | | | | | |
| Ft. In | Miles | | | Head. | Vel. | Head. | Vel. | Head. | Vel. | Head | Vel. | Head | Vel. |
| $\frac{1}{4}$ or 3 | $\frac{1}{6}$ | Dull, | Oaze and Mud, | .0014 | .394 | .0033 | .52 | .0067 | .7 | .0162 | 1.05 | .068 | 2.1 |
| $\frac{1}{2}$ or 6 | $\frac{1}{3}$ | Gliding, | Soft Clay, | .0058 | .787 | .0133 | 1.05 | .0267 | 1.4 | .0647 | 2.1 | .274 | 4.2 |
| 1 | $\frac{15}{22}$ or $\frac{2}{3}$ | Smooth, | Sand, | .0231 | 1.575 | .0532 | 2.1 | .1069 | 2.8 | .259 | 4.2 | 1.036 | 8.4 |
| 2 | $2\frac{1}{3}$ | Uniform Tenors, | Gravel, | .0924 | 2.75 | .2128 | 4.2 | .4276 | 5.6 | 1.036 | 8.4 | 4.344 | 16.8 |
| 3 | $2\frac{1}{22}$ | Ordinary Freshes, | Pebbles, Shivers, and Shingle, | .2079 | 4.325 | .4788 | 6.3 | .9621 | 8.4 | 2.331 | 12.6 | 9.774 | 25.2 |
| 4 | $2\frac{8}{11}$ | | | .3696 | 5.5 | .8412 | 8.4 | 1.7104 | 11.2 | 4.144 | 16.8 | 17.376 | 33.6 |
| 5 | $3\frac{9}{22}$ | Extraordinary Floods and Rapids, | Boulders and Soft Schistus, | .5775 | 7.875 | 1.3200 | 10.5 | 2.672 | 14.0 | 6.475 | 21.0 | 27.15 | 42.0 |
| 6 | $4\frac{1}{11}$ | | Stratified Rocks, | .8316 | 9.45 | 1.9152 | 12.6 | 3.848 | 16.8 | 9.324 | 25.2 | 39.09 | 50.4 |
| 10 | $6\frac{9}{11}$ | Torrents and Cataracts | Indurated Rocks, | 2.3100 | 15.75 | 5.32 | 21. | 10.69 | 28.0 | 25.9 | 42.0 | 108.6 | 84.0 |

The effects of accidents to which rivers are liable may be discovered by this table.—By inspection, it will be seen that, when the velocity is 10 feet per second, or above it, the inundation is such as to carry away every thing before it. The numbers in the latter part of the table are those which the theory assigns; but, in fact, they are impracticable.

The next subject to which our attention shall be directed is the Water-breakers, or, what the workmen call *Sterlings*, being the extremities of the piers which meet and divide the water in its course.

The opinions of engineers respecting the proper form of this part of a bridge are various, some contending for one form, and some for another; but, it is obvious that, the form which divides the water with least resistance, and least contracts the water-way, must be the best; if, at the same time that these advantages are attained, it retains sufficient strength to support the structure.

The right-angled isosceles triangle has been employed by some bridge-builders as a form the most suitable; this opinion arises from the consideration of the right-angle being the strongest of all others; that is, if two bodies meet each other at right-angles, they will overcome a greater resistance than they would do at any other inclination.

Others, again, contend for a form of two arcs, containing each 60°, described from the two angles of the pier, and meeting each other in the line dividing the water; sometimes a semi-ellipse, described on a conjugate equal to the width of the pier, is used; and, not unfrequently, others of the conic sections, or some whimsical figure that pleases the fancy of the architect.

The reasons given by the different individuals who have adopted these forms, may be stated as follows:—Those who adopt the right-angle contend that it divides the stream best, and that a more acute angle would be too weak. Those who use the semi-circle and semi-ellipse, consider that they are the best calculated to resist the shock of a loaded barge, or other floating body, that may come upon them, and that the Gothic arches combine the advantages of both: But we have already observed, that that form must be the best which is best adapted to the figure of the contracted stream, retaining sufficient strength, and allowing the water to pass most freely.

## III.—OF FOUNDATIONS.

A SUBSTANTIAL foundation is of the first importance in masonry, as without it no work can be durable; and yet its construction is usually intrusted to the carpenter and bricklayer: the former for piling inferior, soft, and marshy, grounds; and the latter for raising the wall with little or no masonry.

PLANKING consists in bedding strong boards of oak or fir, the whole length and breadth of the foundation: the former should never be less than three inches, and the latter five, in thickness; and they should be scorched all over, previously to being laid down. Many dilapidations having been occasioned by the decay of planks, the use of them has, by some architects, been lately abandoned.

PILING is had recourse to, where the magnitude of the superstructure requires that the solid earth should be pierced. The piles, which are forced into the earth, are made of fir, oak, &c., usually about nine or ten inches square. Their length is ascertained by boring the ground; the ends of the piles are cased or shoed with pointed iron, and the tops surrounded with the same metal. The machine for forcing these piles consists of a frame of wood, braced with strong pieces of timber, and secured by ledgers and feet; with a cast-iron wheel at the top, about eighteen inches in diameter, and fluted on the outside for a rope, or chain, to move in. This rope, or chain, is attached to the axis of a heavy iron cylindrical beater, which, for general use, weighs about five or seven hundred weight. This cylinder slides sometimes in grooves, in the upright frame, and often on the frame of the upright. A ladder is attached for adjusting the chain, and oiling the machine. It is worked by twenty or more men, each taking hold of a rope for that purpose, and thus raising the beater up and down in the frame. When many piles are to be driven, the great labour will frequently require double sets of men to

work the beater alternately. The piles are driven as close together as can be; the tops sawn off, and the intervals filled up, by the Romans with coals, and by us with chalk and rubble; and the tops *planked* in the usual manner.

In the construction of the London Docks, the piles were all grooved on their opposite sides; and, when driven close to each other, a tongue was forced between to bind the whole together, so as to produce a close chain of wooden piling, from one end of the foundation to the other.

Some architects have not deemed either planking or piling eligible for foundations, within infirm or swampy grounds; and have, therefore, had recourse to a cradle of oak, or fir, in quartering, strongly framed and braced together in bays, and in lengths of from five to ten feet, and of widths proportionate to the superstructure: these frames are again covered over by cross-pieces, or joists, and the whole bedded firmly on the ground, and filled up flush with chalk or rubble. For receiving the foundation of brick or stone walls, this has been found safer than planking; because, if the quarters of the cradle should decay, the rubble would still remain united, and consequently the sinking of the building would be prevented.

The foundations of Bridges are generally laid with dry piers, by the water's being, for a time, turned into a new course, or by erecting a coffer-dam. A *coffer-dam* consists of a double chain of piles, driven into the ground, at a sufficient distance from the intended pier, to admit the work's being conveniently proceeded in; when the piles are all firmly fixed in the earth, strong horizontal beams are framed and bolted to them with braces to stiffen the intermediate parts; they are then finally planked inside and out, so as to form a complete case. The void between each casing is then filled with fat mould, or strong earth, so that very little water can percolate, and this is removed by pumping. A more ingenious method has likewise been practised. It consists of forming a strong grating of timber, covered with planks, which at once forms a floating-raft, and the floor upon which the stone pier is to be erected: the pier built on the raft is composed of stones, amply secured, and rendered, by cement, water-tight; and the whole is so arranged as to float upon the water till it has advanced in height; so that,

if sunk, it should be above low-water mark, or higher, as found expedient. This levity is obtained either by attaching the raft by ropes to vessels, or by the pier's being worked with vacuities sufficient to render it specifically lighter than an equal bulk of water. The pier is sunk either by letting the water into the vacuities, or by loosening the ropes; but the bed of the river should be previously prepared for its reception, by machines of the description of ballast-heavers. Should the bottom of the masonry-ground prove not to be level, it must be raised by pumping the water out, or by means of the machines in the vessels, and the ground then satisfactorily levelled.

In the erection of Westminster Bridge, M. Labelye erected the piers in caissons, or water-tight boxes; the bulk of the box, though loaded with the pier, producing a mass specifically lighter than an equal bulk of water: after each pier had been erected, the sides of the box served again for boxes of other piers; the pier was sunk, and raised as above. Similar caissons were likewise used in erecting Blackfriars' Bridge.

Till of late years the foundation of bridges was erected in the following manner: The piles were driven into the bottom of the river, in the site of the intended pier, and then cut off a little below low-water mark; the interstices being filled with stone and strong cement; on these piles a grating of timber was laid, boarded with thick boarding, and thus was formed the floor for the intended pier. The work was then continued, at low water.

This is a very simple method, requiring no machine beyond a pile-driving engine.

The foundations of the piers of London Bridge, as appeared from that which was removed, when the two small arches were converted into one, was composed of a quadruple row of piles, driven in close together on the exterior site of the pier, and forming a case to receive the stone and cement. So soon as the exterior piles were taken away, the force of the water cleared away the remainder, so that it could not be ascertained whether there were piles in the heart of the pier. To protect the piers of this bridge, sterlings were constructed round them. A *sterling* consists of an enclosure of piles driven close together into the bed of the river, and secured by horizontal

pieces of timber, bolted by iron to the tops of the piles; and the void within, to the piling of the pier, filled with chalk, gravel, stone, &c., so as to form a complete defence to the internal piling, upon which the stone piers are erected.

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## IV.—OF WALLS. (Plate LXXV.)

The antients used several sorts of Walls, in which more or less masonry was always introduced. They had their *recticular* or reticulated *walls*, and also the *incertain:* of these, the *recticulative* kind *(fig.* 2.*)* was the most handsome; but the joints are so ordered, that, in all parts, the courses have an inferior position; whereas, in the *incertain, (fig.* 1.*)* the materials rest firmly one upon another; and are interwoven together, so that they are much stronger than the reticulated, though not so handsome. In this kind of wall the courses were always level; but the upright joints were not ranged regularly or perpendicularly to each other in the alternate courses, nor in any other respect correspondently, but uncertainly, according to the size of the brick or stone employed. Thus our bricks are arranged in ordinary walls, in which all that is regarded is, that the upright joints, in two adjoining courses, do not coincide. Walls, of both sorts, are formed of very small pieces, that they may have a sufficient quantity of, or be saturated with, mortar, which adds greatly to their solidity.

To saturate, or fill up, a wall with mortar, is a practice which ought to be had recourse to in every case, where small stones, or bricks, admit of it. It consists in mixing fresh lime with water, and pouring it, while hot, among the masonry in the body of the wall.

The walls called by the Greeks *Isodomum, (fig.* 4.*)* are those in which all the courses are of an equal thickness; and *Pseudo-isodomum,* or false, *(fig.* 3.*)* when they are unequal. Both these walls are firm, in proportion to the compactness of the mass, and the solid nature of the stones, so that they do not absorb the moistness of the mortar; and, being situated in regular and level

# MASONRY.

*Fig. 1.*

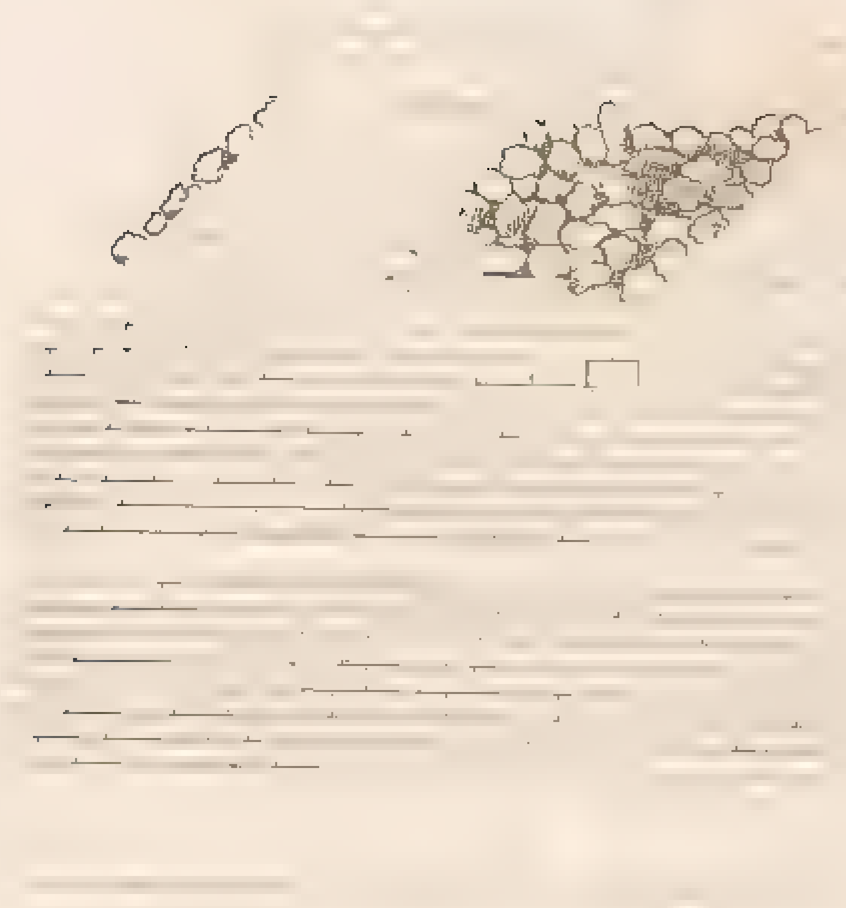


*Fig. 2.*

*Fig. 3*

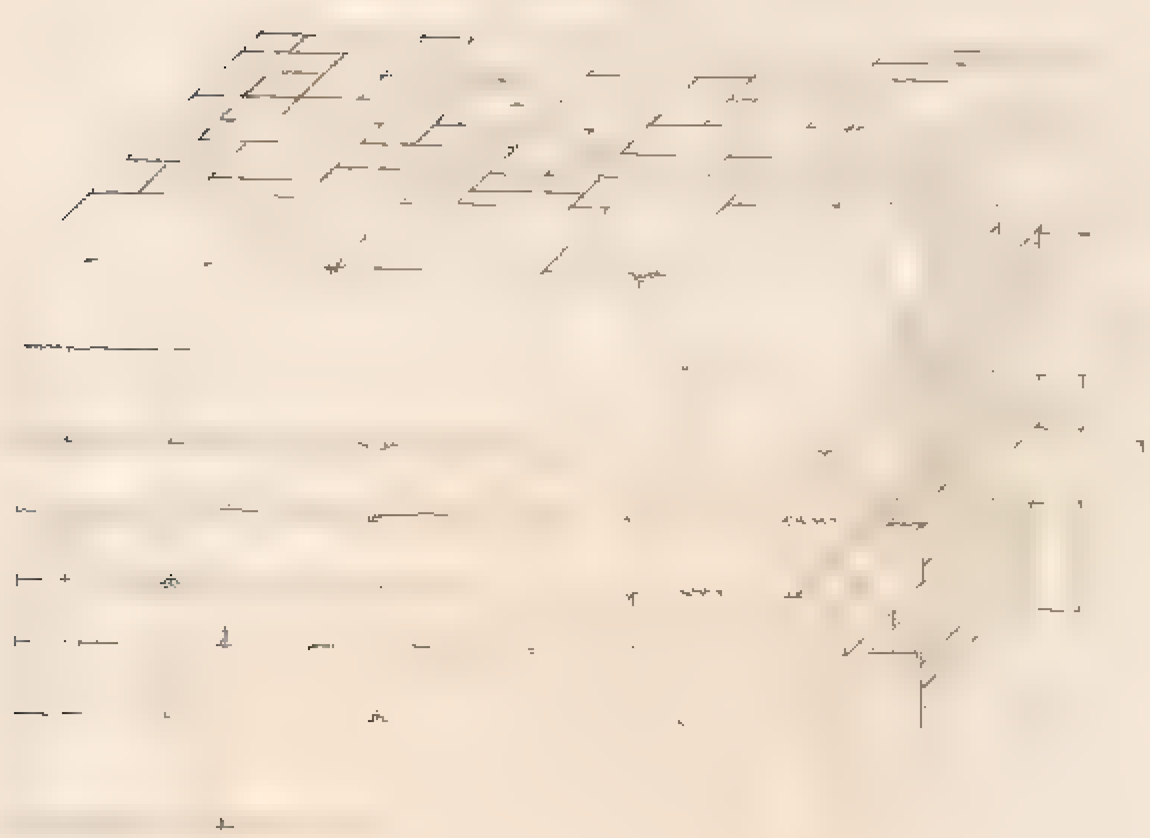


*Fig. 4*

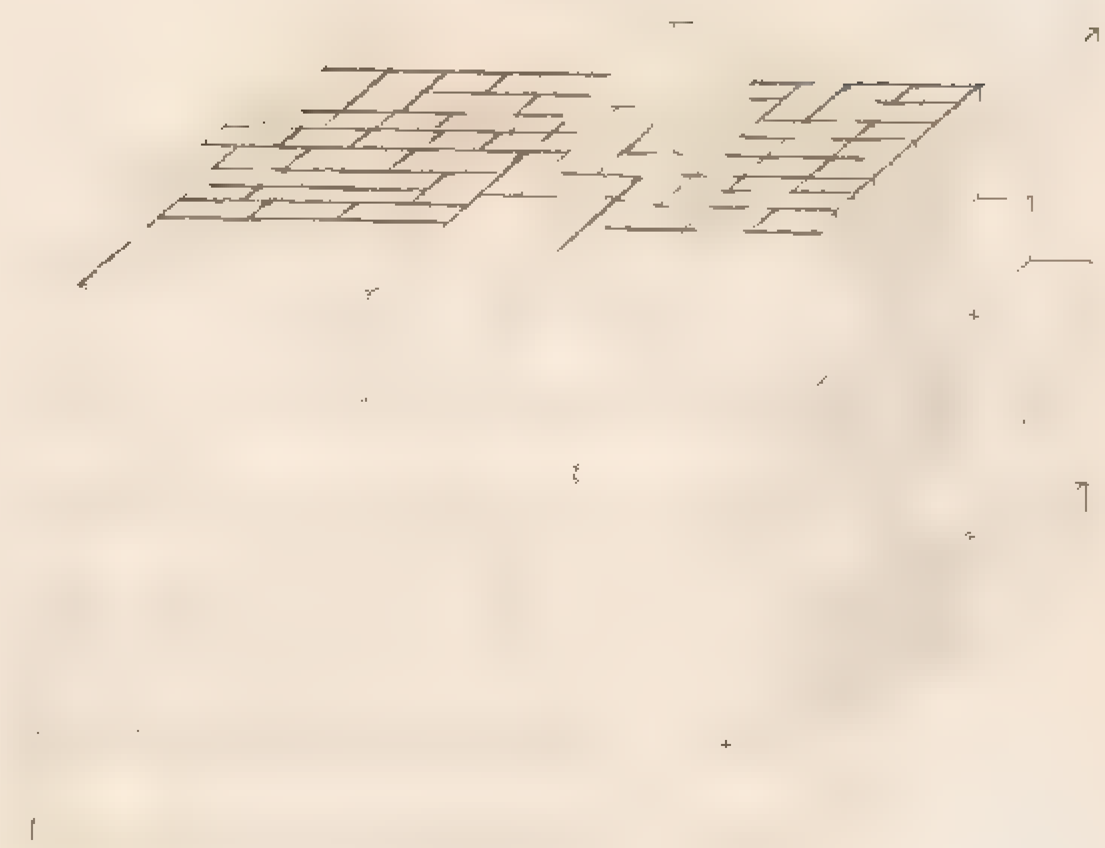


*Fig. 5*

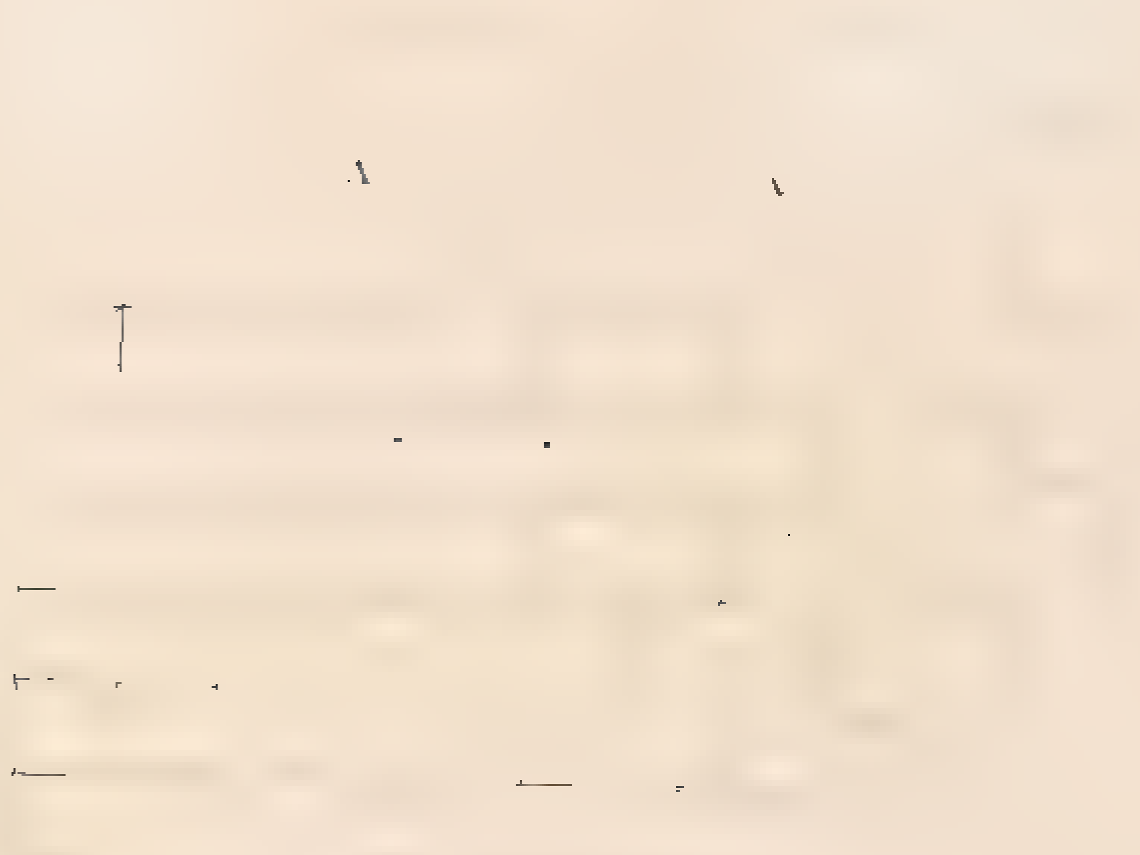
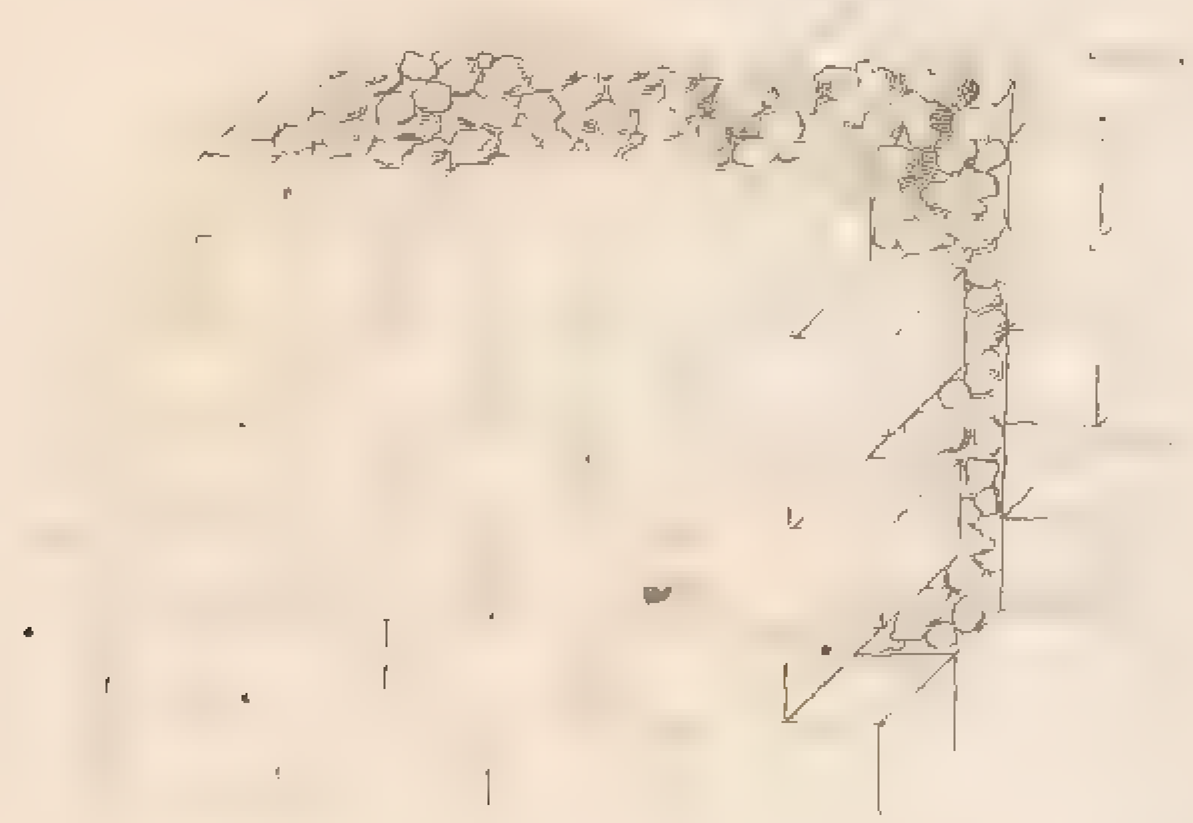


*Fig. 6*



London, Published by Thos Kelly, 17 Paternoster Row, January 1, 1822.

courses, the mortar is prevented from falling, and thus the whole thickness of the wall is united. In the wall called *emplection, (fig. 6.)* the faces of the stones are smooth; the other sides being left as they come from the quarry, and are secured with alternate joints and mortar. This kind of building admits of great expedition, as the artificer can easily raise a case, or shell, for the two faces of the work, and fill the intermediate space with rubble-work and mortar. Walls of this kind, consequently, consist of three coats; two being the faces, and one the rubble cone, which is in the middle: but the great works of the Greeks were not thus built, for, in them, the whole intermediate space between the two faces was constructed in the same manner as the faces themselves *(fig. 5.)*; and they, besides, occasionally introduced *diatonos*, or single pieces, extending from one face to the other, to strengthen and bind the wall. These different methods of uniting the several parts of the masonry of a wall, should be well considered by all persons who are intrusted with works requiring great strength and durability.

The existing examples of *Roman emplection*, with partial cores of rubble work, or brick, sufficiently prove its durability; but that of the Greek was worked throughout the whole thickness of the wall, in the same manner as the facings or fronts, as their temples, now existing, testify.

The walls of modern buildings are sometimes built for ornament, but generally combined with solidity. In London, they are regulated by a specific Act of Parliament; but, to prevent dilapidation, it is necessary to strengthen the walls beyond what the law requires, as this law was framed only as a protection from fire. The thicknesses of walls should be regulated according to the nature of the materials, and the magnitude of the edifice. Walls of stone may be made one-fifth thinner than those of brick; and brick walls, in the basement and ground-stories of buildings of the first-rate, should be reticulated with stones, to prevent their splitting; a circumstance which has been too much disregarded by our present builders.

Having considered those parts of masonry which are essential to all building in general, we shall now proceed to the ornamental or decorative parts of architecture in which masonry is concerned.

## V.—ORNAMENTAL MASONRY.

COLUMNS.—These comprise, generally, a conoidal shaft, with a small diminution towards their upper diameter, amounting, generally, to about one-sixth less than the lower diameter. The proportion of columns, from the Egyptians, varied but little; the columns of this people, in their larger temples, amounting only to about four and a half diameters in height. Those of Greece, as in the *Parthenon*, at Athens, are little more than five. In the best Roman examples, the proportion was increased to upwards of seven diameters. The columns of *all* the Grecian remains are fluted, though in different manners. The Doric shafts have their flutes in very flat segments, finished to an arris: sometimes flutings of the semi-ellipsis shape, with fillets, were adopted.

The genius of an architect is generally displayed in the application of columns. The Greeks surrounded their public walks with them; their porticos carried this kind of splendour to its highest pitch; as in them may be found the whole syntax of architecture and masonry. To construct a temple, in the Greek manner, required the greatest taste and judgment, combined with a perfect knowledge of architecture. The Parthenon, at Athens, exhibits, or rather did exhibit, the most elaborate display of masonry in the world.

The comparatively perfect state in which the monuments of Greece remain, is a proof of the great judgment with which they were constructed. The famous Temple of Minerva would have been entire to this day, if it had not been destroyed by a bomb. The *Propylea*, which was used as a magazine for powder, was struck by lightning and blown up. The Temple of Theseus, having escaped accidental destruction, is almost as entire as when first erected. The little choragic monument of Thrasybulus, as well as that of Lysicrates, are also entire. These instances should impress on modern architects the utility of employing large blocks, and of uniting them

with the greatest accuracy; without which masonry is not superior to bricklaying. The core of the rubble-work of the Grecian walls is impenetrable to a tool; which is an additional proof of the care which was taken in cementing their masonry.

The joining of columns in free-stone, has been found more difficult than in marble; and the practice used by the French masons, to avoid the failure of the two arrisses of the joint, might be borrowed with success for constructing columns of some of our softer kinds of free-stone. It consists in taking away the edge of the joints, by which means a groove is formed at every one throughout the whole column. This method is employed only in plain shafts. It appears to have been occasionally used by the antients, though for a different purpose; *viz.* to admit the shaft to be adorned with flowers, and other insignia, on the occasion of their shows and games. In the French capital, they affix rows of lamps on their colûmns, making use of these grooves to adjust them regularly, which produces a very good effect.

The shafts of columns, in large works, intended to be adorned by flutes, are erected plain, and the flutings chiselled out afterwards. The antients commonly formed the two extreme ends of the fluting previously, as may be seen in the remaining columns of the Temple of Apollo, in the Island of Delos; a practice admitting great accuracy and neatness. The finishing the detail of both sculpture and masonry on the building itself, was an universal practice among the antients: they raised their columns first in rough blocks, on them they placed the architraves and friezes, and surmounted the whole by the cornice; finishing down only such parts as could not be got at in the building; hence, perhaps, in some measure, arose that striking proportion of parts, together with the beautiful curvature and finish given to all the profiles in Grecian buildings.

PILASTERS, in modern design, are frequently very capriciously applied. They are vertical shafts of square-edged stone, having but a small projection, with capitals and bases like columns; they are often placed by us on the face of the wall, and with a cornice over them. In Greek architecture,

they are to be met with commonly on the ends of the walls, behind the columns, in which application their face was made double the width of their sides; their capitals differing materially from those of the accompanying columns, and somewhat larger at bottom than at top, but without any *entasis* or swell.

PARAPETS.—Parapets are very ornamental to the upper part of an edifice. They were used by the Greeks and Romans, and are composed of three parts; viz. the *plinth,* which is the blocking course to the cornice; the *shaft* or *die,* which is the part immediately above the plinth; and a cornice, which is on its top, and projects in its moulding, sufficiently to carry off the rain-water from the shaft and plinth. In buildings of the Corinthian style, the shaft of the parapet is perforated in the parts immediately over the apertures in the elevation, and balustrade-enclosures are inserted in the perforations. The architects have devised the parapet with reference to the roof of the building which it is intended to obscure.

ASHLARING is a term used by masons to designate the plain stone work of the front of a building, in which all that is regarded is getting the stone to a smooth face, called its *plain work.* The courses should not be too high, and the joints should be crossed regularly, which will improve its appearance, and add to its solidity.

CILLS.—These belong to the apertures of the doors and windows, at the bottom of which they are fixed; their thickness varies, but is commonly about one inch and a half; they are also fluted on their under edges, and sunk on their upper sides, projecting about two inches, in general, beyond the ashlaring.

CORNICE.—This forms the crown to the ashlaring, at the summit of a building; it is frequently the part which is marked particularly by the architect, to designate the particular order of his work; hence ***Doric, Ionic,*** and *Corinthian,* cornices are employed, when, perhaps, no column of either is used in the work; so that the cornice alone designates the particular style of the building. In working the cornice, the top or upper side should be splayed away towards its front edge, that it may more readily carry off the

water. At the joint of each of the stones of the cornice, throughout the whole length of the building, that part of each stone which comes nearest at the joints, should be left projecting upwards a small way; a process by workmen called *saddling* the joints; this is done to keep the rain-water from entering them, and washing out the cement. These joints should be chased or indented, and such chases filled with lead, and even when dowels of iron are employed, they should be fixed by melted lead also.

RUSTICATING, in architecture and masonry, consists in forming horizontal sinkings, or grooves, in the stone ashlaring of an elevation, intersected by vertical or cross ones; perhaps invented to break the plainness of the wall, and denote more obviously the bond of the stones. It is often formed by splaying away the edge of the stone only; in this style, the groove forms the elbow of a geometrical square. Many architects omit the vertical grooves in rustics, so that their walls present an uniform series of horizontal sinkings. There are many examples, both antient and modern, of each kind.

ARCHITRAVES adorn the apertures of a building, projecting somewhat from the face of the ashlaring; they have their faces sunk with mouldings, and also their outside edges. When they traverse the curve of an arch, they are called *archivolts*. They give beauty to the exterior of a building, and the best examples are among the Greek and Roman buildings.

BLOCKING COURSE.—This is a course of stone, traversing the top of the cornice to which it is fixed; it is commonly, in its height, equal to the projection of the cornice. It is of great utility in giving support to the latter by its weight, and to which it adds grace. At the same time, it admits of gutters behind it to convey the superfluous water from the covering of the building. The joints should always cross those of the cornice, and should be plugged with lead, or cramped on their upper edges with iron. The Romans often dove-tailed such courses of stone.

FASCIA is a plain course of stone, generally about one foot in height, projecting about an inch before the face of the ashlaring, or in a line with the plinth of the building: it is fluted or *throated* on its upper edge, to prevent the water from running over the ashlaring; its upper edge is sloped

downwards for the same purpose. It is commonly inserted above the windows of the ground-stories; *viz.* between them and those of the principal story.

A PLINTH, in masonry, is the first stone inserted above the ground: it is in one or more pieces, according to its situation, projecting beyond the walls above it about an inch, with its projecting edge sloped downwards, or moulded, to carry off the water that may fall on it.

IMPOSTS.—These are insertions of stone, with their front faces generally moulded; when left plain, they are prepared in a similar manner to the facias. They form the spring-stones to the arches in the apertures of a building, and are of the greatest utility.

## VI.—THE CONSTRUCTION OF DOMES.

The Construction of a Dome is less difficult than that of an arch, because the tendency, which each part has to fall, is not only counteracted by the pressure of the parts above and below, but also by the resistance of those on each side. Thus a dome may be erected, not only without the centring which an arch requires, but it may likewise be left open at the top, without any key-stone.

The masonry of domes differs from that of arching, in the figure of each voussoir, which must fit the void in a sphere instead of its sections. If a dome rises nearly vertical, with its form spherical, and of equal thickness, it should be confined with a chain, or hoop, as soon as the rise reaches to about $\frac{11}{14}$ths of its whole diameter, in order that the lower parts may not be forced out: but, if the masonry is diminished in thickness as it rises, this precaution will not be necessary.

The dome of the antient Pantheon, at Rome, built by order of Augustus, is nearly circular, but its lower parts are made sufficiently thick to resist the pressure of the upper parts; moreover, the spreading is prevented by several projections, which answer the purpose of abutments and buttresses.

At the restoration of the arts in Italy, many attempts were made to imitate the dome of the Pantheon; but the skill of the architect was, in general, insufficient for ensuring success.

Anthemius, a Grecian architect, was selected by the Emperor Justinian, for erecting a dome to the church of St. Sophia, at Constantinople, which church was to be in form of a cross, and vaulted with stone; this dome he attempted to raise on the heads of four piers, about 115 feet high, and at the same extent from each other, with four buttresses to aid the piers. The buttresses were solid masses of stone, extending, at least, ninety feet from the piers to the north and south, so as to form the side walls of the cross. These effectually secured the piers from the thrust of the two great arches of the nave which supported the dome. But, when the dome was finished, and had stood a few months, as there was no provision against the thrust of the great north and south arches, the two eastern piers, with their buttresses, were soon pushed from their perpendicular; and, consequently, the dome and half-dome fell in. On the death of Anthemius, Isidorus, another Grecian, succeeded to the work, and, having filled up some hollows to strengthen the piers on the east side, again began to raise the dome; but, while one part was building, another part fell in. It was now found that the pillars and walls of the eastern semi-circular end were too much shattered to give any resistance to the push which was directed against them; and therefore several clumsy buttresses were erected on the eastern wall of the square which surrounded the Greek cross. These were roofed in, so as to form a kind of cloister, and lean against the piers of the dome, and thus oppose the thrust of the great north and south arches. The dome was now turned for the third time; and though it was extremely flat, and, except the ribs, roofed with pumice-stone, it was soon found necessary to fill the whole, from top to bottom, with arcades, in three stories, to prevent the dome falling a third time. Thus a dome, which was intended to be a beautiful specimen of architecture, was rendered a mis-shapen mass of deformity and ignorance. This example should warn the architect not rashly to undertake what he has not sufficient science, in a proper manner, to perform.

Since that time, several domes have been erected in various parts of Europe, that display every requisite of beauty and strength, peculiar to this species of building. St. Peter's, at Rome, is a superb specimen; and St. Paul's, at London, though it is more remarkable for its carpentry than its masonry, developes equal talent. The dome of the Hospital of Invalids, at Paris, is a beautiful work; and that of the church of St. Genevieve, including the peristyle on which it rests, is, perhaps, the most beautiful specimen in existence, as to form and composition. The peristyle is formed by fifty-two columns of the Corinthian order, each about fifty feet high, completely insulated, and standing on a circular stylobat. Above the cornice of the peristyle, the dome arises in a beautiful curved line to the top, on which is formed a pedestal and gallery. But, when the dome was raised, the columns composing the interior began to sink with the weight; and some of the shafts of the columns decorating the interior, which consisted of four naves, with the lantern and dome over them, began to fracture at the joinings; this defect was removed by walling up the inter-columniation at the four quarters of the screen, which thus preserved from dilapidation one of the finest monuments of taste and genius.

The last specimen which we shall mention is the rotunda of the Bank of England, erected on the principles of the Pantheon, at Rome. The dome takes its spring from a wall of great thickness, and is furnished with several projections externally, which answer the purposes of buttresses. It is open at the summit, which lights the whole of the interior of the building. This is an unique specimen, and bears very honourable testimony to the talents of its constructor, Sir Robert Taylor.

## VII.—VALUATION OF MASONS' WORK.

To all the distinct parts of masons' work, a certain value is assigned for the labour and expense of erection and execution.

Masons' work is generally measured with two rods, about five feet long, each divided into feet, halves and quarters of feet, and sometimes inches; but

the common rule is generally applied to measure the smaller fractions. Stone-work, exceeding two inches in thickness, is valued by cubic feet; if less than two inches, it is reckoned as slabs, and valued by superficial feet. All kinds of ornamental work, as groovings, flutings, joints, rebats, throatings, copings, &c., are valued by the running foot. The dimensions are put down in a book, ruled in three divisions on its left-hand side, the middle being about one-third of those on its sides, and is used for the inches and parts: the left-hand column is for the feet and the number of times the dimensions are to be repeated; and the right-hand column for the quantities, when cubed and squared; for it often happens that there are several pieces of the same size, and these are marked down, as well as the the nature of the stone, and the species of labour required for working it. The dimension-book will thus stand in the following manner:—

| | | | | | |
|---|---|---|---|---|---|
| 3 | 6 | : 0 | | | |
| | 3 | : 0 | $\dot{3}$ | : $\ddot{4}\frac{1}{4}$ | Portland Landing. |
| | | : 9 | | | |
| 6 | 7 | : 6 | 84 | : 4 | Plain Work Do. |
| | 3 | : 9 | | | |
| 3 | 7 | : 6 | 22 | : 6 | Groove Do. |

Thus every portion of material and labour is accurately ascertained. After this has been done, a loose sheet of paper is ruled into as many columns as there are species of work, which is written over the head of each: as, beginning with cube of Portland-stone, is placed in the column under that head; and the same for plain-work, sunk-work, moulded-work, and each species of running-work, separately. They are cast up at the bottom of each column, and from them made out into bills, beginning with cubes, then superficies; and, lastly, ornamental-work. For measuring, cubing, squaring, valuing, and finishing the account, surveyors are allowed two and a half per cent. on the gross amount.

*Plain-work* consists merely in the cleaning up of its surface, and all is measured which is seen.

*Sunk-work* is that which has been partly chiselled away, as the tops of window-cills, &c.

*Moulded-work* is that which is formed into various forms on the edges, as cornices, architraves, &c. The dimensions of moulded-work are ascertained by girting the whole round with a piece of tape, over and into all its several parts; the length of the tape will give the width of the moulded-work, and then taking its length, and squaring them together, the superficial quantity of moulded-work will be given. A distinct valuation is attached to each kind of labour; and, as this varies in different places, it would be of little use to insert any here. In London, however, the prices are uniform for each separate kind.

## VIII.—DESCRIPTION OF THE SECTIONS OF ARCHES.
### (Plate LXXVI.)

To describe a Parabolic Arch, the span and height of the arch being given—

Method 1.—*Figures* 1 and 2.—Let AB be the span: Bisect AB in the point C, and draw CD perpendicular to AB. Make CD equal to the height of the arch. Produce CD to E; making DE equal DC, join EA, EB. In AE set off the distances A1, A2, A3, &c., so that the parts may be all equal; and, in EB, set off the parts E1, E2, E3, &c., so that the differences may be all equal. Join the corresponding points 1,1; 2,2; 3,3; &c. and the intersections of the several lines will form the parabola required.

Fig. 1 is adapted to a segment, where the rise of the arch is considerable. Fig. 2 is adapted to the head of an aperture, where the radius of curvature of the arch is very great, or where the deflection of the curve from a straight line is but small.

Method 2.—*Figure* 3.—AB and CD being as before, draw DE parallel to AB, and AE parallel to CD. Divide AC into any number of equal parts, and AE into the same number. From the points 1, 2, 3, &c. in AE, draw

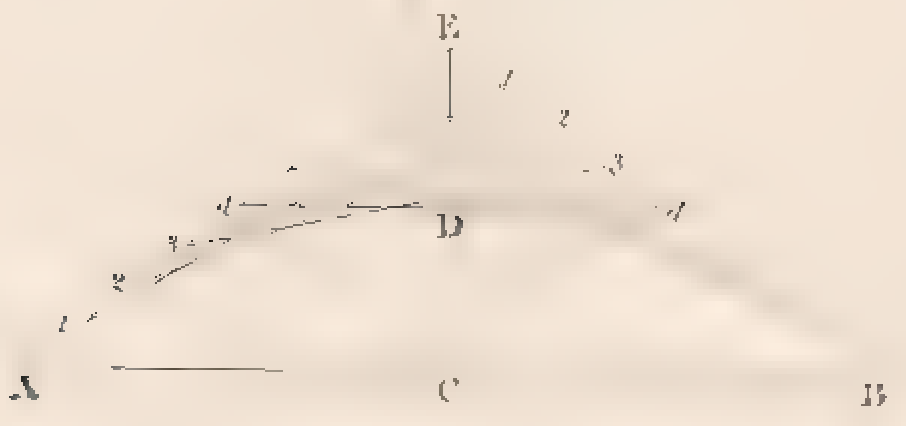


Fig. 1

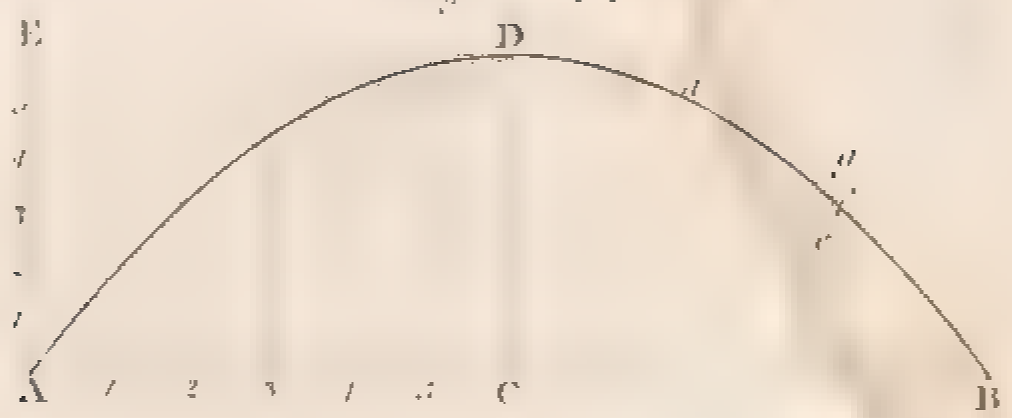


Fig. 3.

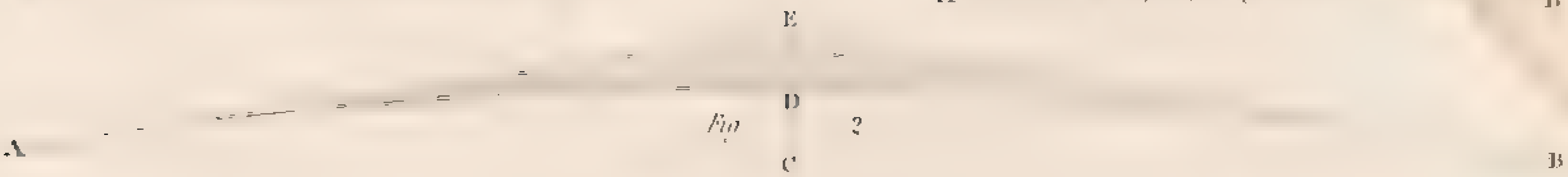


Fig. 2

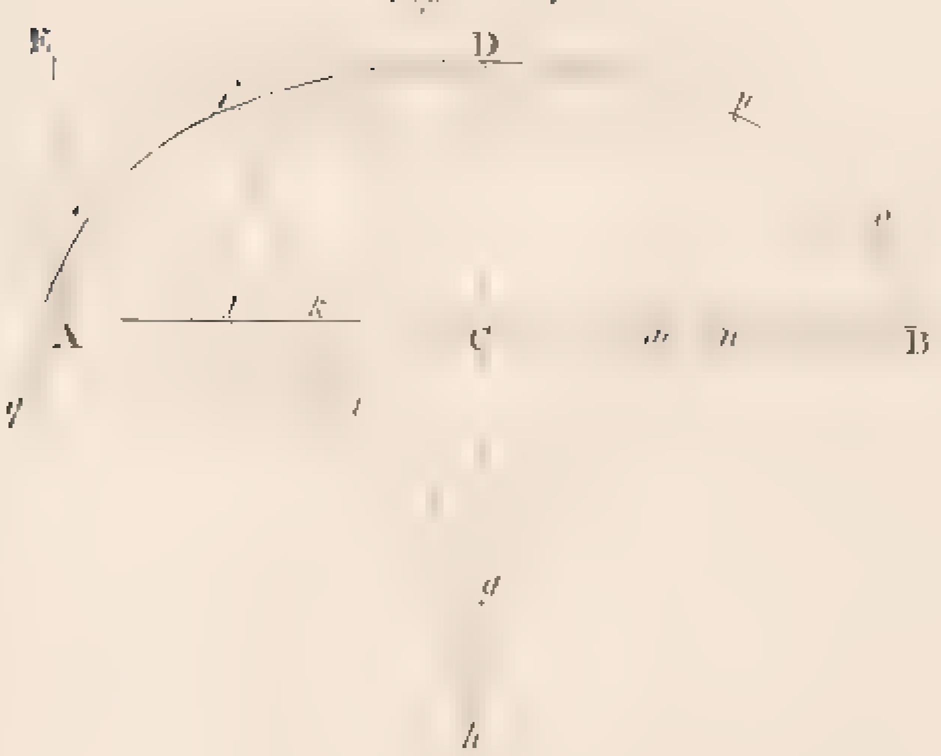


Fig. 4

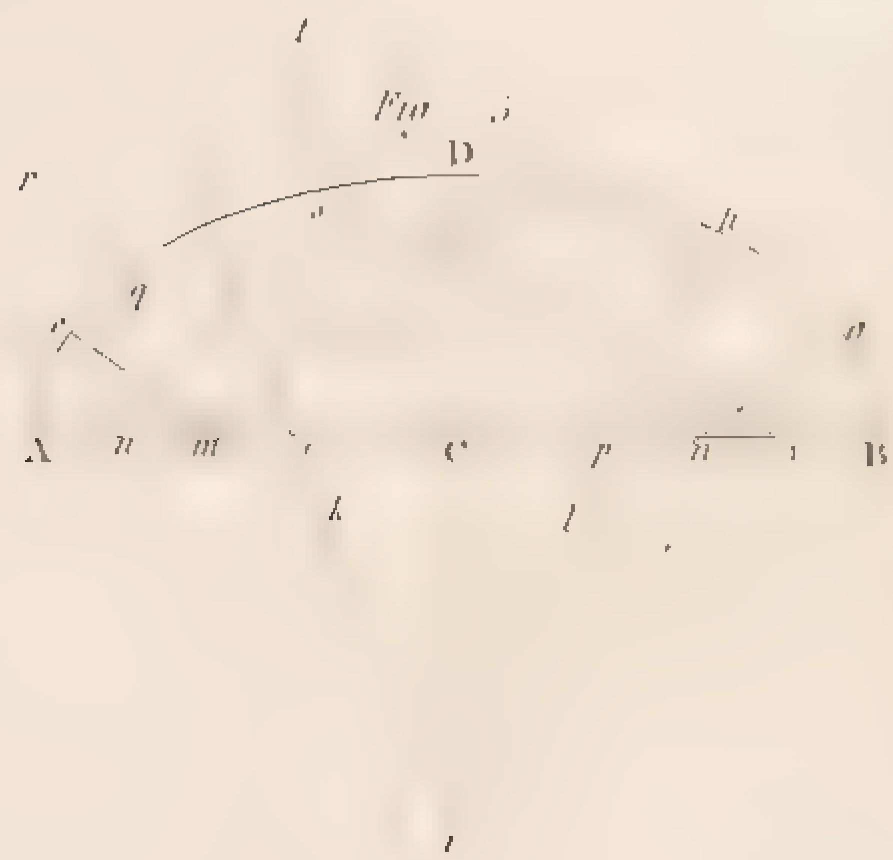


Fig. 5

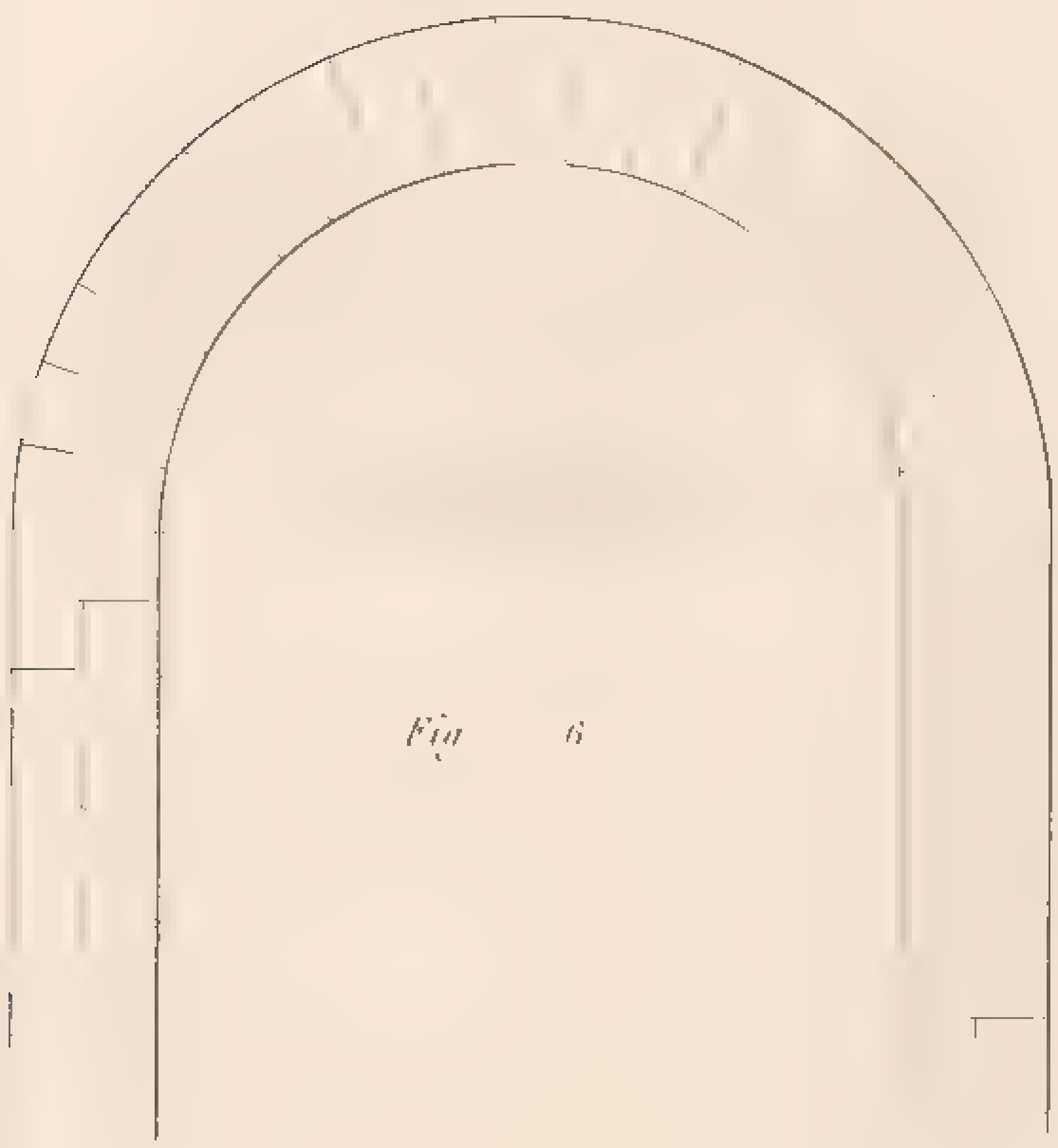


Fig. 6


Fig. 7

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lines to D, intersecting perpendiculars to A, drawn from the points 1, 2, 3, &c., in AC. Through the points of intersection draw the curve AD. In the same manner draw the curve BD.

To draw a straight line perpendicular to the curve from a given point *h*, (*fig.* 3,) as a joint.

In the curve take any other point, as B, at pleasure, and join B*h*. Bisect B*h* in *e*, and draw *eg* perpendicular to AB, intersecting the curve in the intermediate point *f*. Make *fg* equal to *fe*; join *eg*, and draw *hi* perpendicular to *eg*; then *hi* will be the joint required.

### A PRACTICAL METHOD *of describing the* CURVE *of an* ARCH, *and of drawing the joints.* (*Figure* 4.)

Let AB be the axis major. Bisect AB in C, and draw CD perpendicular to AB, and make CD equal to the semi-axis minor. Draw DE and AE, respectively parallel to AB and CD. Divide AC and AE each into three equal parts. Produce DC to *g*, and make C*g* equal to CD. Draw lines from the points of division in AE to the point D, to intersect other lines in *ef*, drawn from *g* through the points of division in AC; then, *e* and *f* will be points in the curve.

Bisect *f*D by a perpendicular, meeting D*g* produced in *h*, and join *hf*, intersecting AC in *k*. Bisect *ef* by a perpendicular, meeting *gh* in *i*. Draw *iq* parallel to AB. From *i*, with the radius *if*, describe the arc *fq*. Join *q*A, and produce *q*A to meet the arc *fq*: join the point of meeting, and the point *i* intersecting AB in *l*.

From *h*, with the radius *h*D, describe an arc D*f*; from *i*, with the radius *if*, describe an arc *fe*; and from *l*, with the radius *lc*, describe the arc *c*A.

By placing the centres in the same position, the other half, DB, of the semi-elliptic arc, ADB, will be described.

### *To* DRAW *a* TANGENT *to a semi-elliptic arch, the axis-major being horizontal.* (*Figure* 5.)

Find the focii *u* and *v*. Let *s* be a point in the curve: join *su* and *sv*.

Draw $st$, bisecting the angle $usv$, and $st$ will be the joint required. In the same manner any other joint, $qr$, will be found.

Or, by finding the position of the centres, and that of the lines for describing the curve, as in *fig.* 4, the joints may be drawn, as $qr$ from $k$, $st$ from $i$.

*Figure* 6 is a semi-circular arch, with the joints marked out.

*Figure* 7 a semi-elliptic arch, with the joints also marked out, and the centres for drawing them as before.

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## IX.—STONE-CUTTING, &c.

### A SEMI-CIRCULAR RIGHT ARCH. *(Plate* LXXVII.*)*

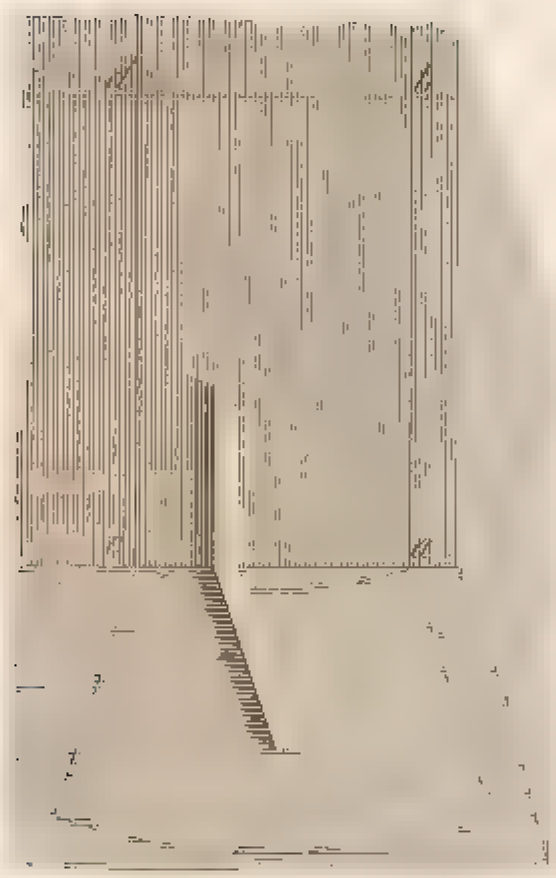
Let ABCD, *(figure* 4,*)* be the plan of the arch. Divide the opening into two equal parts by the perpendicular EF; from E, with the radius of the intrados, describe the semi-circle AFB; and, from the same point E, with the radius of the extrados, describe the semi-circle GHI. Divide the arch GHI, of the extrados, into five equal parts, and draw the radiating lines $ko$, $lp$, $mq$, $nr$, for the joints, which will form the heads of the arch-stones.

The horizontals and perpendiculars are not drawn as in the last example, because the stones may be formed without making a mould for each stone, by having the head of the arch-stone and thickness of the wall only, in the following manner:

Choose a stone of sufficient length to answer the thickness of the wall, and of such breadth and depth as to answer the other dimensions. Reduce the side intended for the intrados to a plane surface, on which draw the two parallel lines $ab$, $cd$, *(fig.* 1,*)* distant from each other the space between the joints of the intrados; then square one end, as, $ac$ to $abcd$, and parallel to $ac$ draw $bd$, at a distance equal to the thickness of the wall. Square the other end of the stone, and on the head apply the mould $pqml$, *(fig.* 4,*)* so that its extremities $pq$ may coincide with $ca$, *(fig.* 1,*)* when applied to one head, and with $bd$ when applied to the other; then hollow out the intrados, and cut the joints or beds according to the traces, as exhibited at *figure* 2.

# MASONRY.

Fig. 1



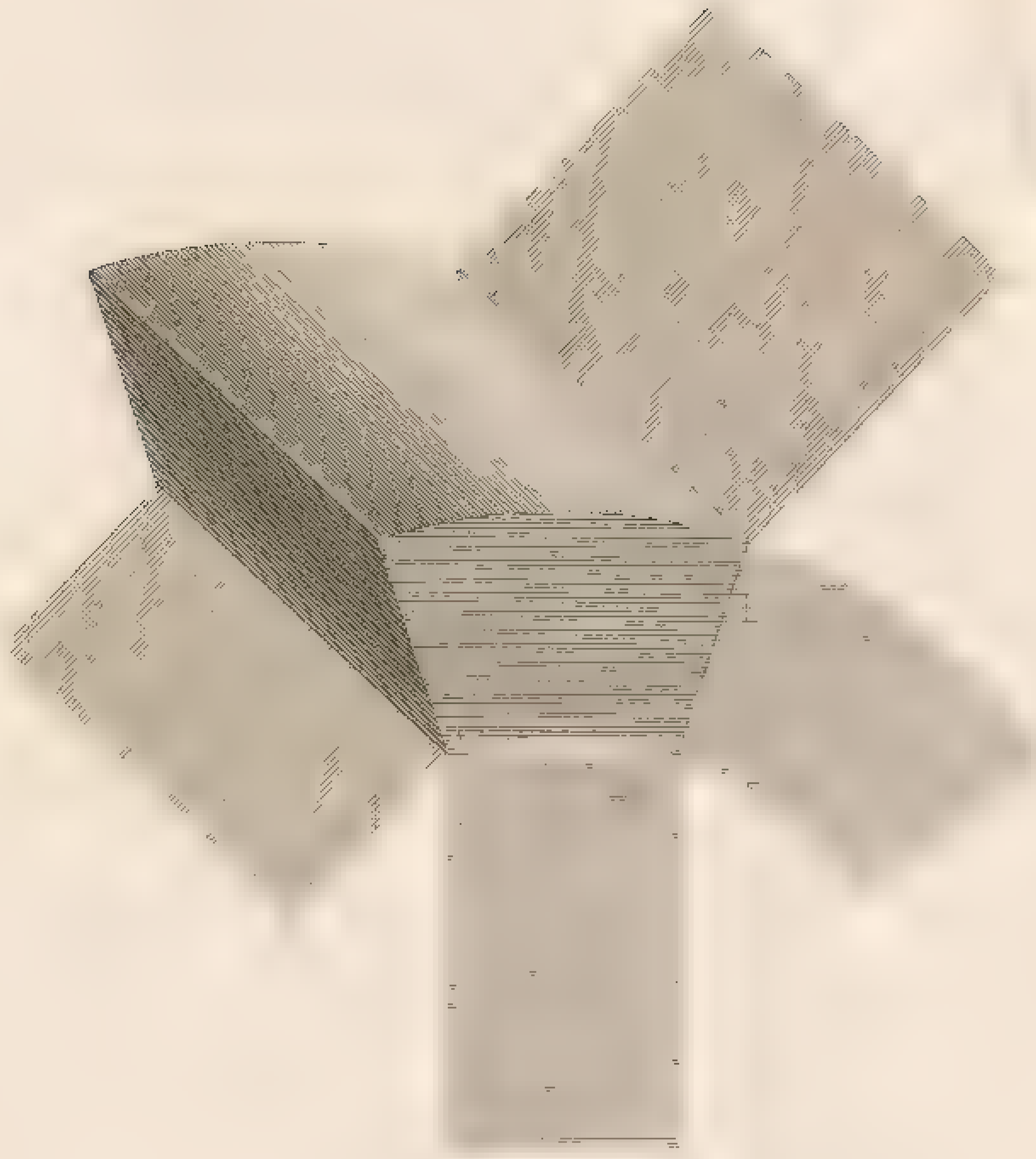
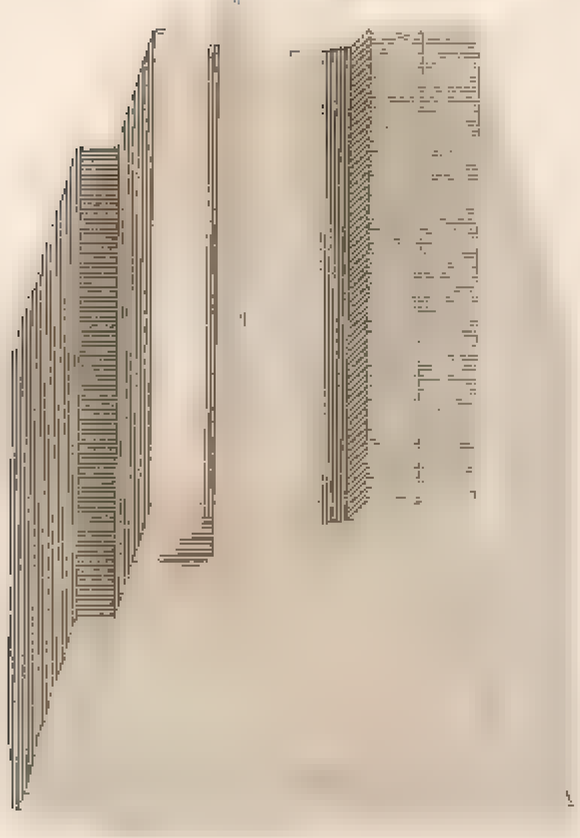


Fig. 2



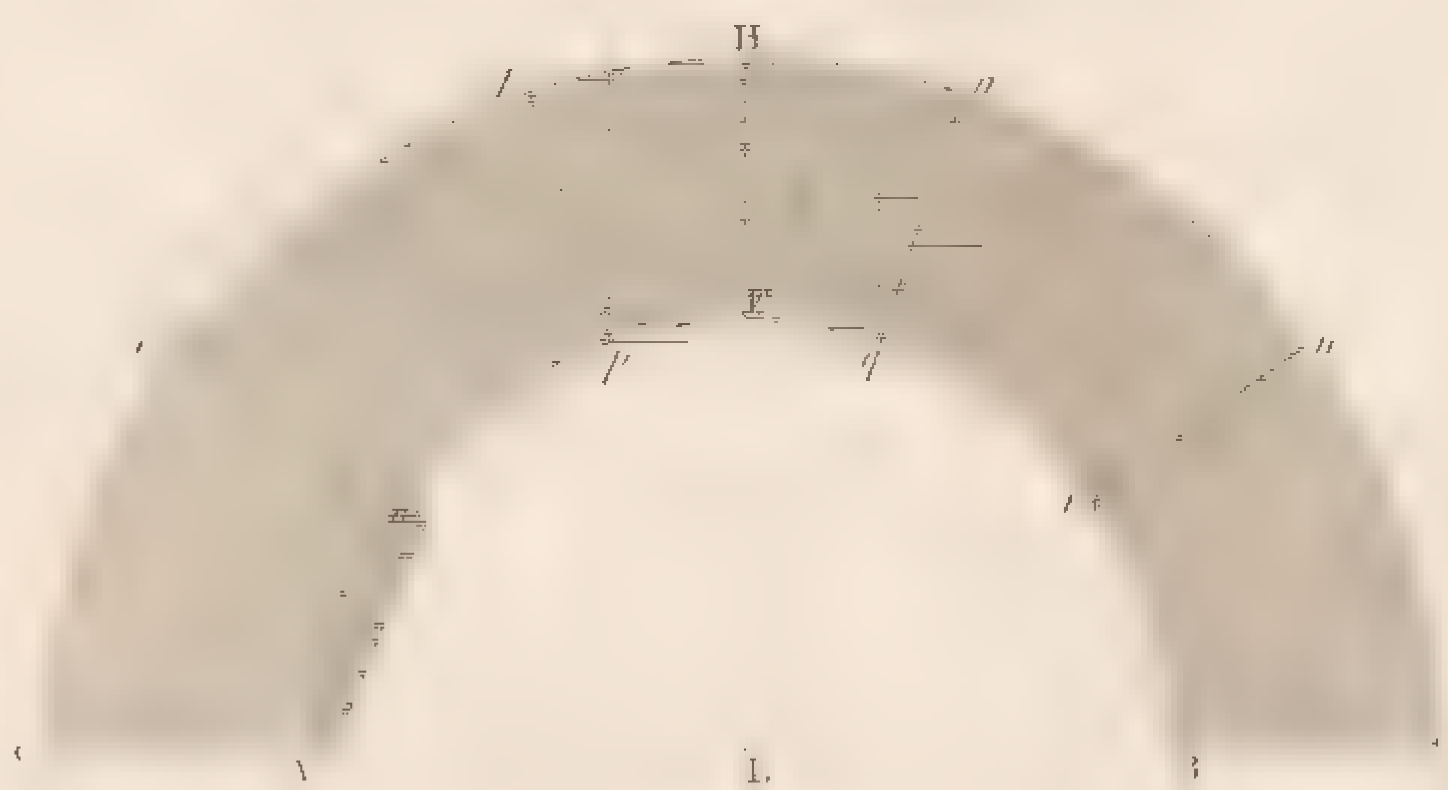
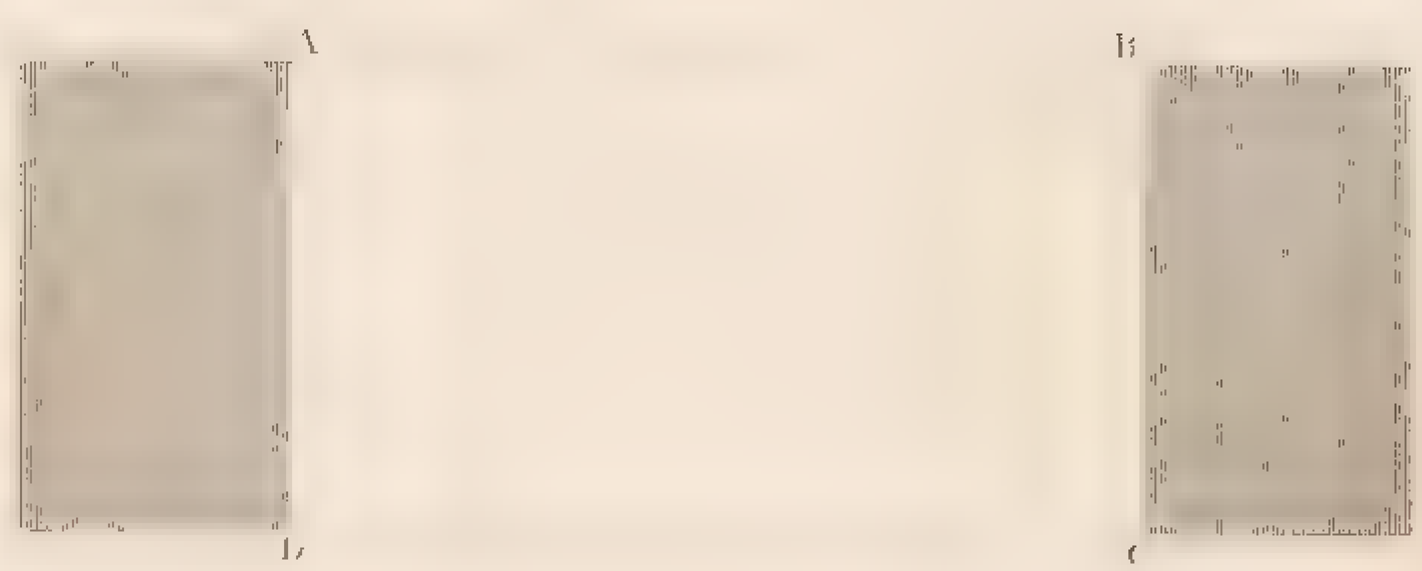



Fig. 3

Fig. 4



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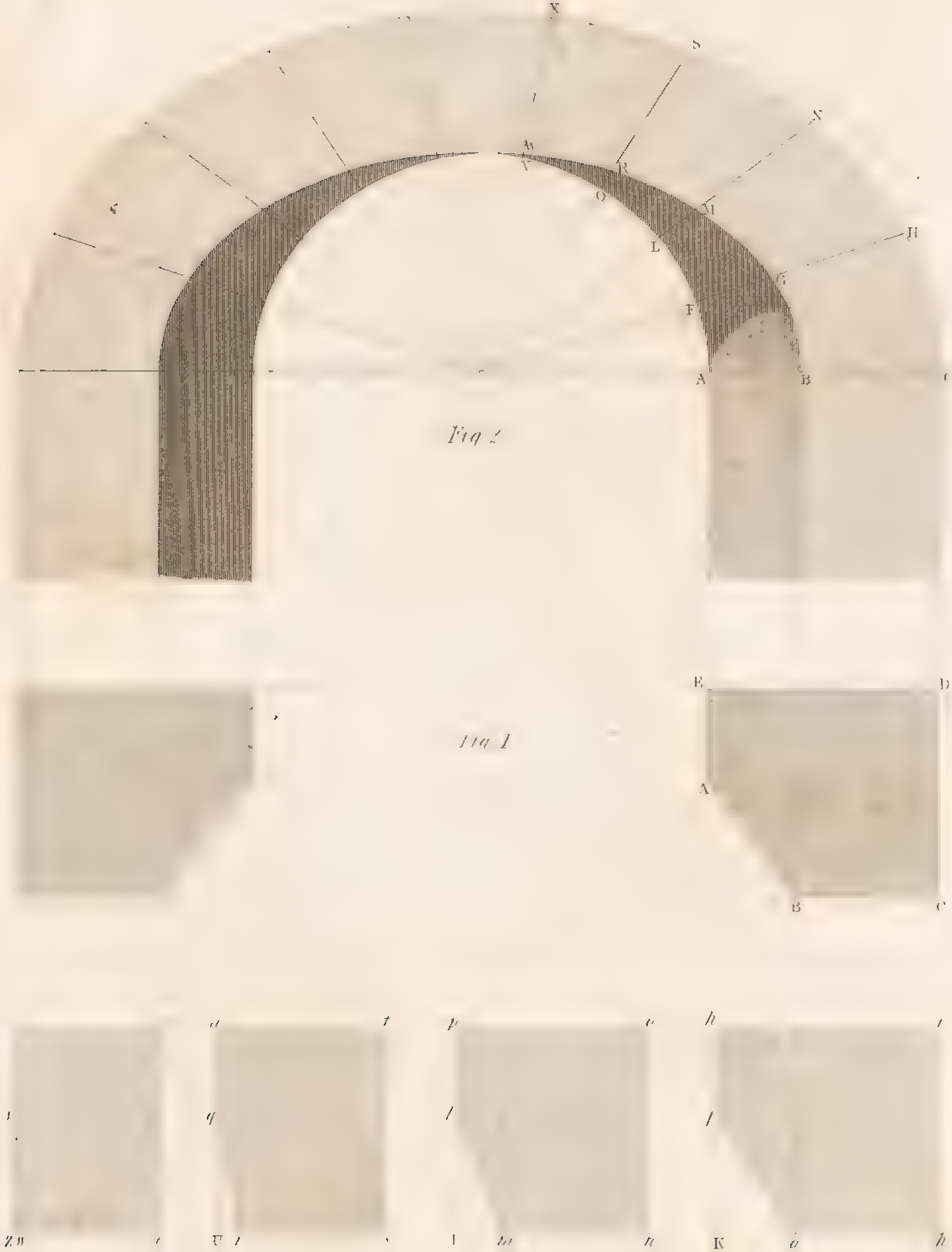



Engraved by R.Rosse

Fig. 1

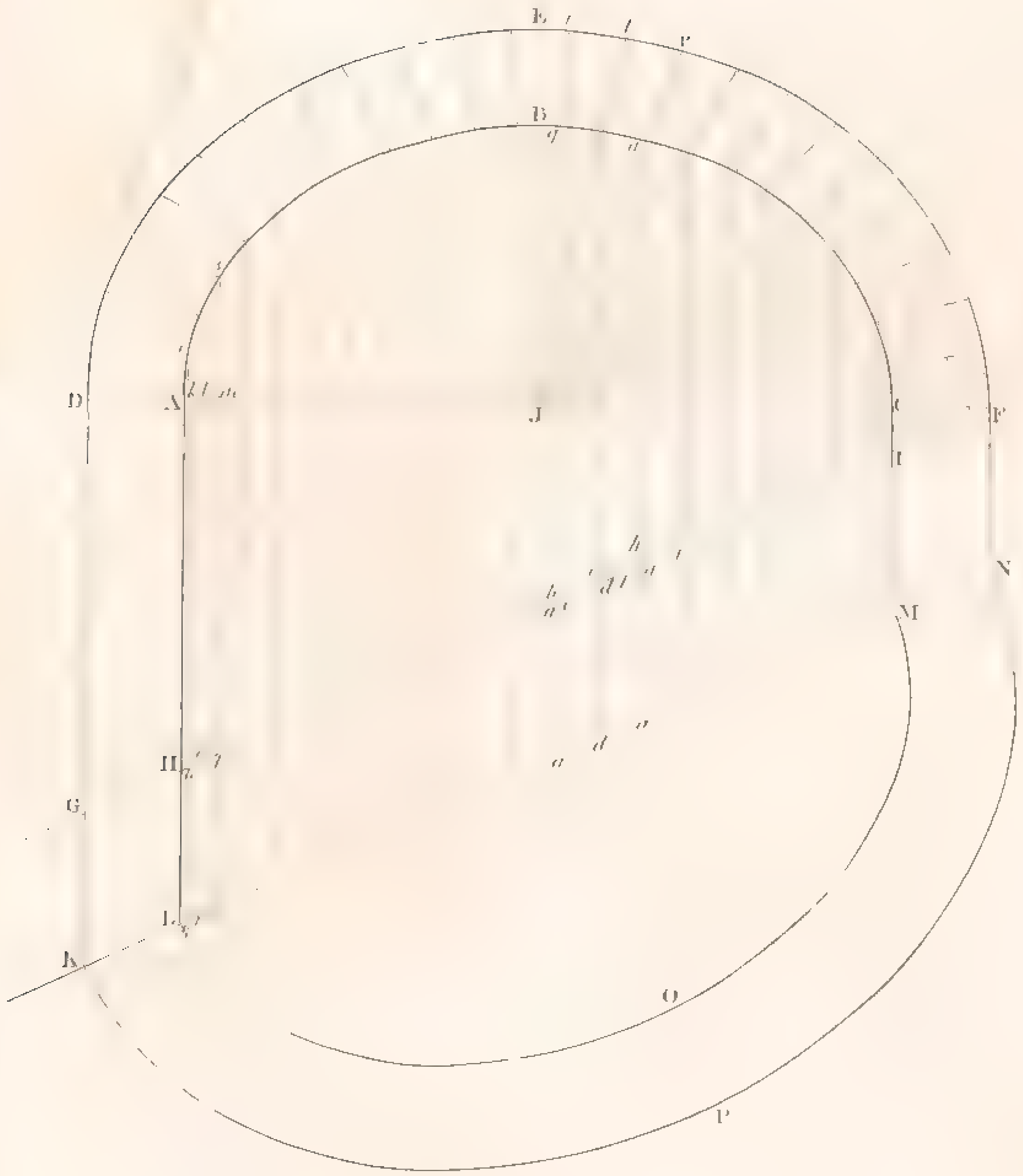
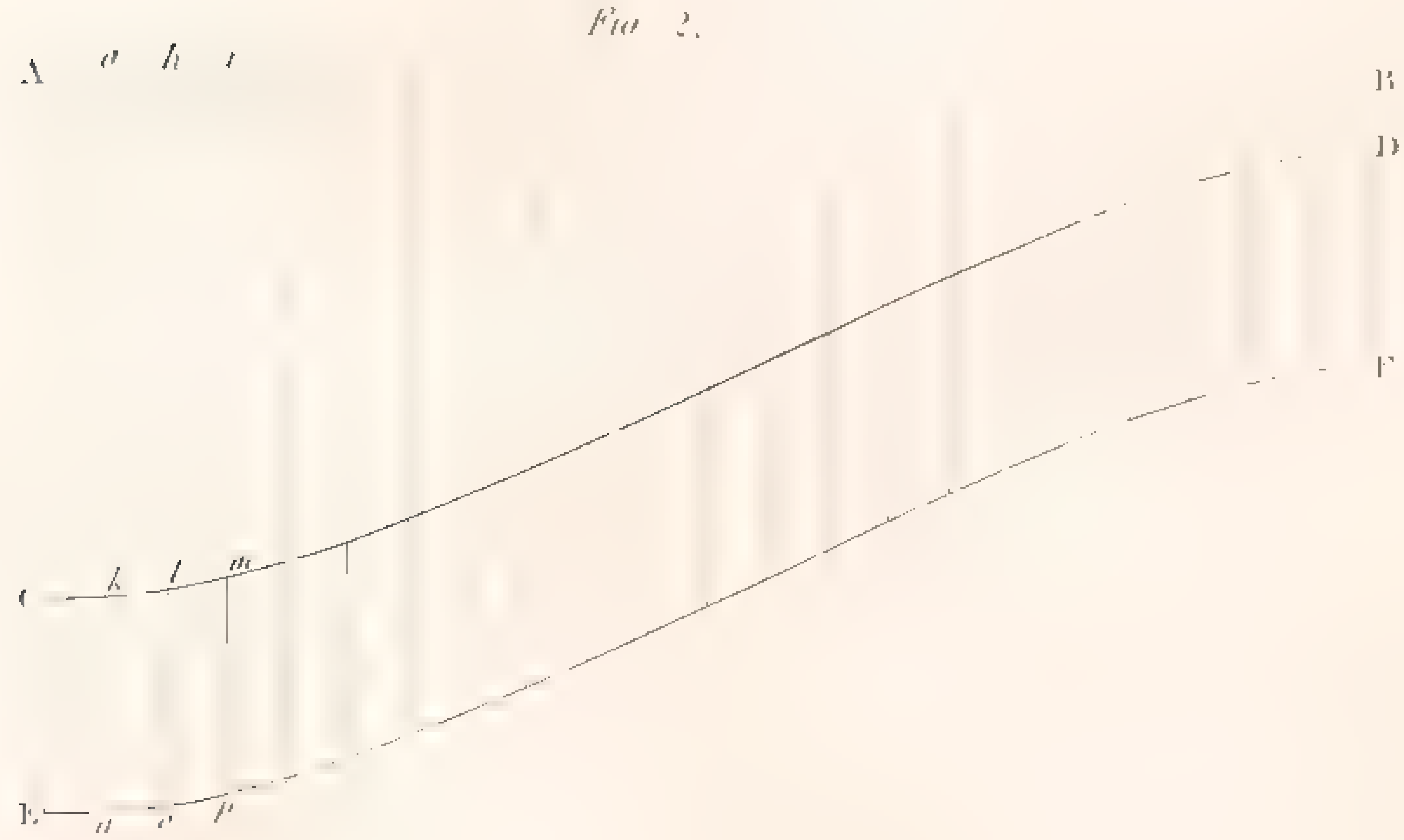


Fig. 2



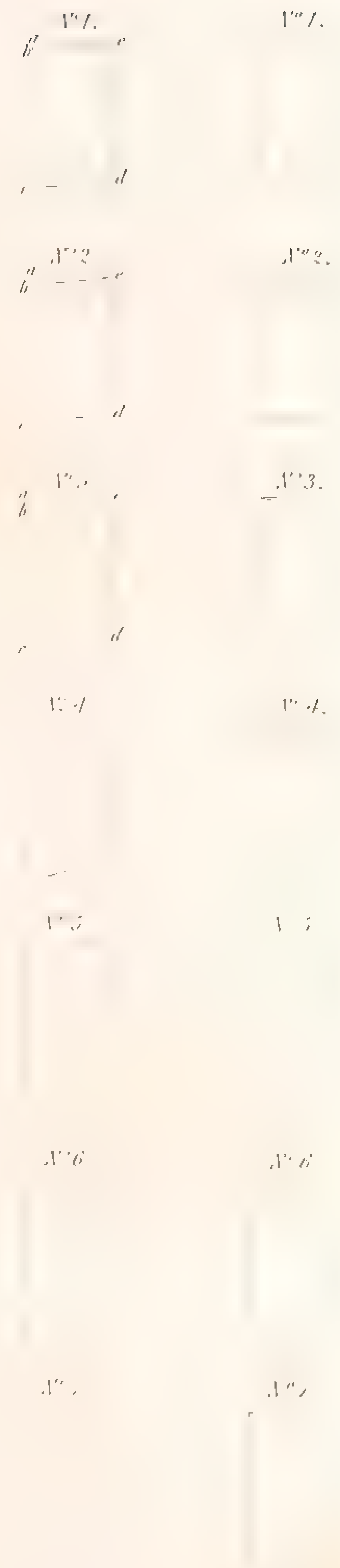


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*Figure* 3 exhibits a stone entirely finished, and all the others are formed after the same manner; but, instead of forming the heads on the stones themselves, a bevel, such as shewn in *fig.* 4, *ko*A′, may be used with advantage.

The higher part of *fig.* 4 represents an arch-stone, accompanied with the moulds of each side, which will explain the application more particularly.

The middle part of *figure* 4 shows the arch complete, with all the stones supporting one another.

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## THE ELLIPTICAL ARCH, WITH SPLAYED JAMBS. *(Plate* LXXVIII.*)*

*To find the angles of the joints formed by the front and intrados of an Elliptical Arch, erected on splayed jambs.*

*Figure* 1, on the plate, is the plan of the Imposts.

*Figure* 2, the Elevation.

The impost A′B′C′D′E′ is the first bed; *fghik*, the second; *lmnop*, the third; *qrstu*, the fourth; *vwxyz*, the fifth: The other beds are the same in reverse order. The breadth of all these beds is the same as that of the arch itself. The lengths *k*K, *n*P, *s*U, *x*Z, of the front lines of the moulds of the beds are respectively equal to the lines HF, NL, SQ, XV, on the face of the arch. And also, *hg*, *nm*, *sr*, *xw*, on the fronts of the moulds equal to the corresponding distances HG, NM, SR, XW, on the face of the arch. The distances *kf*, *pl*, *uq*, *zv*, are each equal to the perpendicular part AE of the impost.

---

## TO FIND THE JOINTS OF AN ARCH IN MASONRY.

Let ABC *(Plate* LXXIX.*)* be the *intrados*, and DEF be the *extrados*, of the arch. Draw DK, AL, CM, FN, perpendicular to the base DF, of the arch. Make the angle DFG equal to the angle which the wall makes with the jambs of the arch, and draw KN, at a distance from GF, equal to the thickness of

the wall; then the plan of the wall is represented by GFNK; the abutment on one side, or springing base, is represented by GHLK, and that on the other side by FIMN. Let J be the centre of the given arch.

Divide ABC, the intrados of the arch, into as many equal parts as the arch-stones are in number. Through the points 1, 2, 3, &c., draw lines 1*q*, 2*r*, 3*s*, &c., cutting the one side KN of the wall at *q*, *r*, *s*, &c., and the other side at *n*, *o*, *p*, &c.

In *figure* 2, draw the straight line AB, and make AB equal to the stretch out of the arc ABC, and let A*g*, *gh*, *hi*, be equal to the distances on the arc ABC. Draw the perpendiculars ACE, *gkn*, *hlo*, &c. Make AC equal to AH, *figure* 1; *gk* equal to *kn*, *figure* 1; *hl* equal to *lo*, *figure* 1; *im* equal to *mp*, *figure* 1; and so on: then through the points C, *k*, *l*, *m*, &c., to D, draw the curve line CD. Likewise make AE, *gn*, *ho*, *ip*, &c. respectively equal to AL, *kq*, *ms*, &c. (*fig.* 1.); then, through all the points E, *n*, *o*, *p*, &c. to F, draw the curve EF, which will complete the whole developement of the intrados of the arch.

The parts C*kn*E, *klon*, *lmpo*, &c., are the heads, or exact forms, of the ends of the stones of the arch, and therefore the moulds of the ends of the arch-stones must be made to correspond to these figures.

*To find the bevels of the joints of the stones.*—Let *q*, *s*, *u*, (*fig.* 1.) be the points of division on the intradosal line, next to the crown of the arch.

From the centre J, and through the points *q*, *s*, *u*, &c., draw the lines J*r*, J*t*, J*v*, &c., then *qr*, *st*, *uv*, &c. will represent the joints of the arch. From the points *q*, *s*, *u*, &c., draw *qa*, *sd*, *ug*, &c., parallel to AH, cutting GF in the points *a*, *d*, *g*, &c.; and, from the points *r*, *t*, *v*, &c., draw *rc*, *tf*, *vi*, &c., parallel to AH, cutting GF in the points *c*, *f*, *i*, &c. Draw *bc*, *ef*, *hi*, &c. parallel to DF.

Then, to find the bed of the stone answering to the joint *qr*, draw the straight line *abc*, No. 1, and make *ab* equal to *ba*, *figure* 1. Draw *ae* perpendicular to *ac*, and make *ae* equal to *qr*, *figure* 1; and make *ac*, No. 1, equal to GK or HI, &c. In No. 1, draw *cd* parallel to *be*, and *ed* parallel to *ac*; then will the figure be formed of the bed of the stone.

# MASONRY.


*Fig. 1*



*Fig. 2*

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In the same manner we may form No. 2, to the joint $st$; and No. 3, to the joint $uv$; and so on.

Nos. 1, 2, 3, 4, 5, &c. are the forms of the moulds for the beds of the right-hand arch-stones; and Nos. 1, 2, 3, &c. reversed on the right-hand, are the moulds for the beds of the arch-stones on the left-hand: viz. No. 1, and No. 1, are the two bed-moulds next to, and on each side of, the crown; No. 2, and No. 2, are the second equi-distant bed-moulds from the crown.

In working the stones, the beds ought to be numbered the same as the moulds, in order that the arch-stones may be readily applied together.

The stone-cutter may first work one of the beds, and cut the form of the mould upon the bed of the stone.

---

### OBLIQUE CIRCULAR ARCH. (*Plate* LXXX.)

Let ABNO (*figure* 1.) be the face of an oblique arch, of which $rsmn$ is the plan; AM$rm$, OQ$sn$, the imposts; $rm$ and $sn$ being the jambs.

Suppose, then, that the obliquity of the arch were given, with the number of stones requisite for its construction, the figure of the stones may be obtained by the following construction:—

Find the centre C, of the span $rs$, which join with the points of division in the arch, by the straight lines CB, CN, &c. At the point C, in $rs$, make the angle $r$CD equal to the given obliquity; in CD take any point, as P, and from P, draw PE, meeting $r$C perpendicularly in E: Upon EC describe the semi-circle E$abc$C, cutting the joints produced in the points $a, b, c$: with the distances E$a$, E$b$, E$c$, describe arcs meeting EC in the points $a', b', c'$; join P$a'$, P$b'$, and P$c'$, then will P$a'r$, P$b'r$, and $Pc'r$, be the angles of the faces of the stones to which they are referred.

Again, to find the angle of the bed: upon PC describe the semi-circle P$a''b''c''$C; and, from C, with the distances C$a$, C$b$, C$c$, cut the semi-circle in $a''b''c''$; join P$a''$, P$b''$, and P$c''$, then PC$a''$, PC$b''$, and PC$c''$, will be the angles of the bed.

Calculation.—In the triangle PCE we have given the angle at C equal to the obliquity, and the side, CP, any magnitude at pleasure; hence the sides PE and EC can be found: then, in the triangle EC$a$, we have given the angle at C, and the side EC to find E$a$ equal to E$a'$; lastly, in the triangle EP$a'$ we have given the sides PE, E$a'$, to find the angle P$a'$E, which is the angle made by the face of the stone and its bed.

The general formula is cot. req. ang. = cot. obliquity × sin. $\frac{180° \times m}{n}$, where $n$ is the number of stones in the arch, and $m$ any multiplier in the natural series, 1, 2, 3, &c.

The angle formed by two contiguous boundaries of the bed is found exactly as the last.

The formula is cos. req. ang. = cos. obliquity × cos. $\frac{180° \times m}{n}$.

As a particular example, suppose the obliquity to be 73°, and the number of stones 11, and the respective angles will be exhibited in the following Table :—

| | Divisions of the Arch. | Face Angles. | Bed Angles. |
|---|---|---|---|
| 1 | 16°„ 21′„ $49\frac{1}{11}$″ | 85°„ 4′„ 37″ | 73°„ 42′„ 29″ |
| 2 | 32 „ 43 „ $38\frac{2}{11}$ | 80 „ 36 „ 52 | 75 „ 45 „ 41 |
| 3 | 49 „ 5 „ $27\frac{3}{11}$ | 76 „ 59 „ 23 | 78 „ 57 „ 42 |
| 4 | 65 „ 27 „ $16\frac{4}{11}$ | 74 „ 27 „ 31 | 83 „ 1 „ 25 |
| 5 | 81 „ 49 „ $5\frac{5}{11}$ | 73 „ 9 „ 46 | 87 „ 36 „ 55 |

The angles for the remaining divisions being the supplements to those in the table, it is unnecessary to give them here.

To apply the formulæ to a numerical Example, we will take the first division in the table—

Formula first: 
- Cot. 73° .............. Log. —1.485339
- Sin. 16°„ 21′„ $49\frac{1}{11}$″ —— 9.449836
- Cot. 85 „ 4 „ 37 .. —— 8.935165

Formula second:
- Cot. 73° .............. Log. —1.465935
- Cos. 16°„ 21′„ $49\frac{1}{11}$″ —— 9.982042
- Cos. 73 „ 42 „ 29 .. —— 9.447977

# MASONRY.


Fig. 2

Fig. 1

Fig. 3

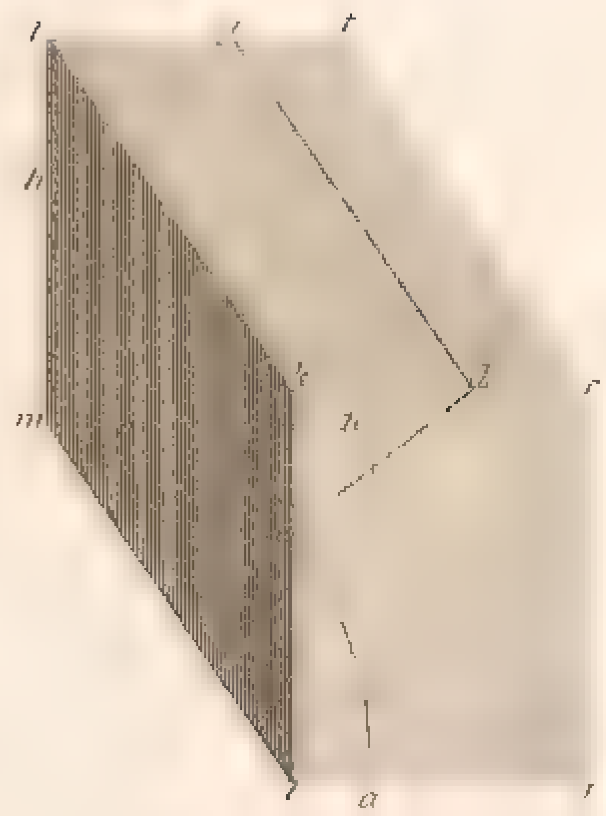



Fig. 4

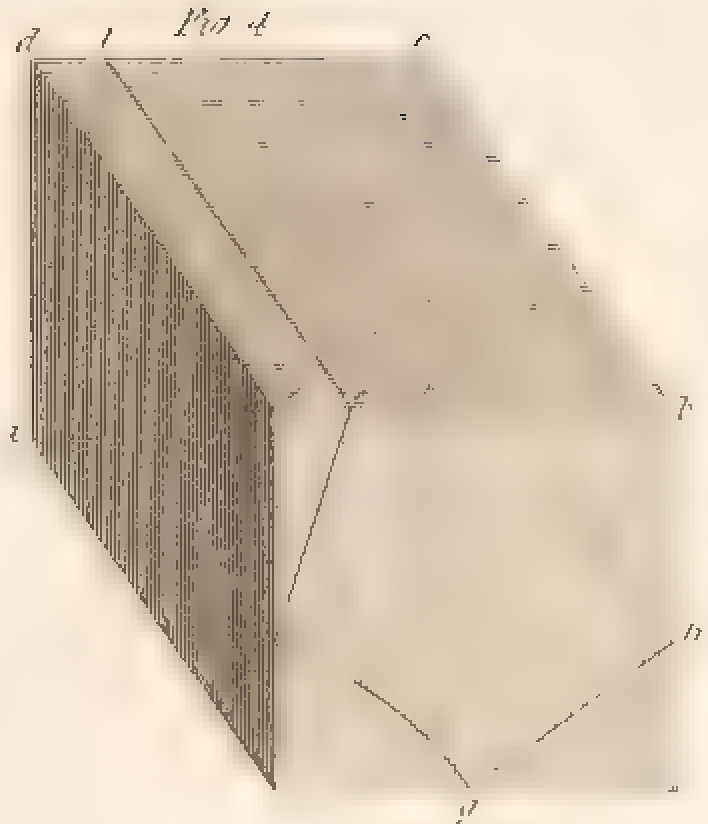



Fig. 6

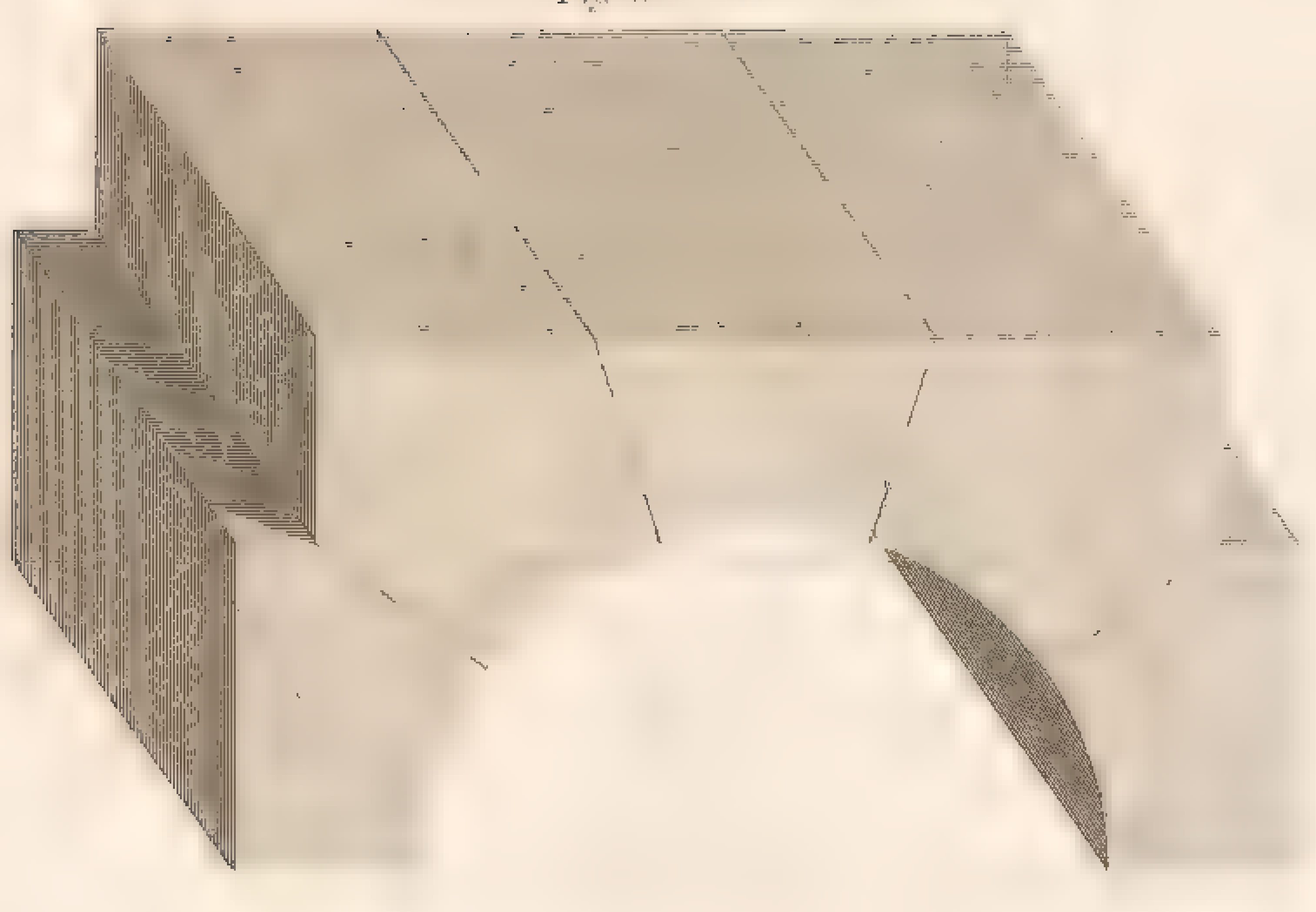
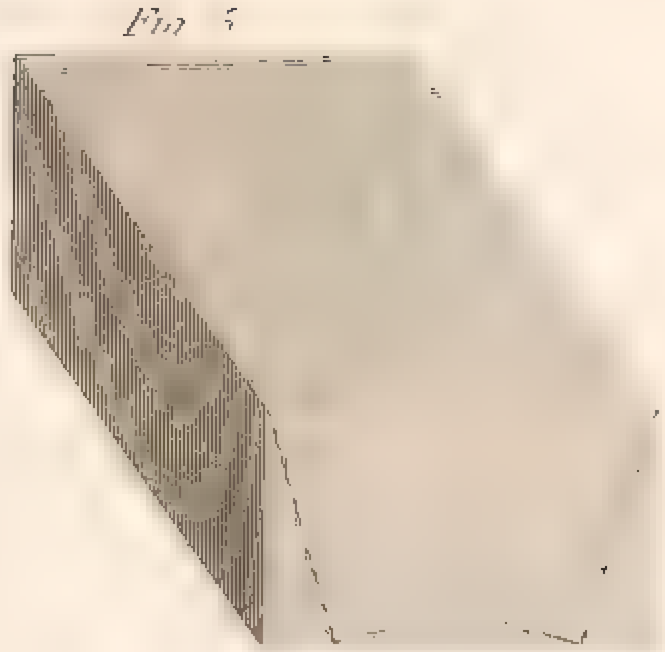


Fig. 5



Engraved by R. R. Ite

London, Published by Thos Kelly, 17, Paternoster Row, Octr 1, 1824.

One of the stones, when finished, will appear as in *figure* 2; where PDE and QRC are the two angles requisite in its construction; PDE being the angle of the face, and QRC the angle of the bed.

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## OBLIQUE ARCH. *(Plate* LXXXI.*)*

Let ABCD, *(fig.* 1,*)* be the plan, parallel to which draw D′C′, *(fig.* 2,*)* on which, as a diameter, describe the semi-circle D′FC′; divide the arc D′FC′ into as many equal parts as the proposed number of stones to be in the arch, which, in the present instance, is five. Draw the joints of the face tending to the centre E; draw also the horizontals and perpendiculars of the intradoses marked by dotted lines in the figure.

*To form the first arch-stone.*—On the impost HBCL make a bed to a stone, that will suit the plan of the bevel HIKL, and work the four adjacent sides each at right angles to HIKL. Apply the mould MNOP *(fig.* 2.*)* to the two ends, so that MN may coincide with KL and IH; the stone being thus guaged, make the upper and under beds parallel to each other. The stone, being now brought to the square, as seen at *fig.* 3, apply the mould C′NORQC′, *(fig.* 2.*)* so that NO may coincide with *bc*, and C′N with *ab*. Draw *dg*, *eh*, and *ap*, parallel to the arris *kl*, then work off the joint *dghe* and the intrados *aehpa*, and the first arch-stone will be finished.

Having made the upper surface of the second stone, as in *fig.* 4, apply to it the mould STUV, *(fig.* 1,*)* forming the parallelogram *abcd*, *(fig.* 4.*)* Then work off the four adjacent sides to a right angle with it, then guage the stone to its depth, and work off the lower horizontal surface; apply the mould of the head to the ends of the stone, as in working the first arch-stone, and draw the receding lines, then work the joints and the intrados as before, and the stone will be finished.

The key-stone, exhibited in *figure* 5, is wrought in the same manner, and the whole arch, as completed, is represented by *figure* 6.

## A SEMI-CIRCULAR ARCHED PASSAGE, BETWEEN TWO SEMI-CIRCULAR ARCHED VAULTS. (*Plate* LXXXII.)

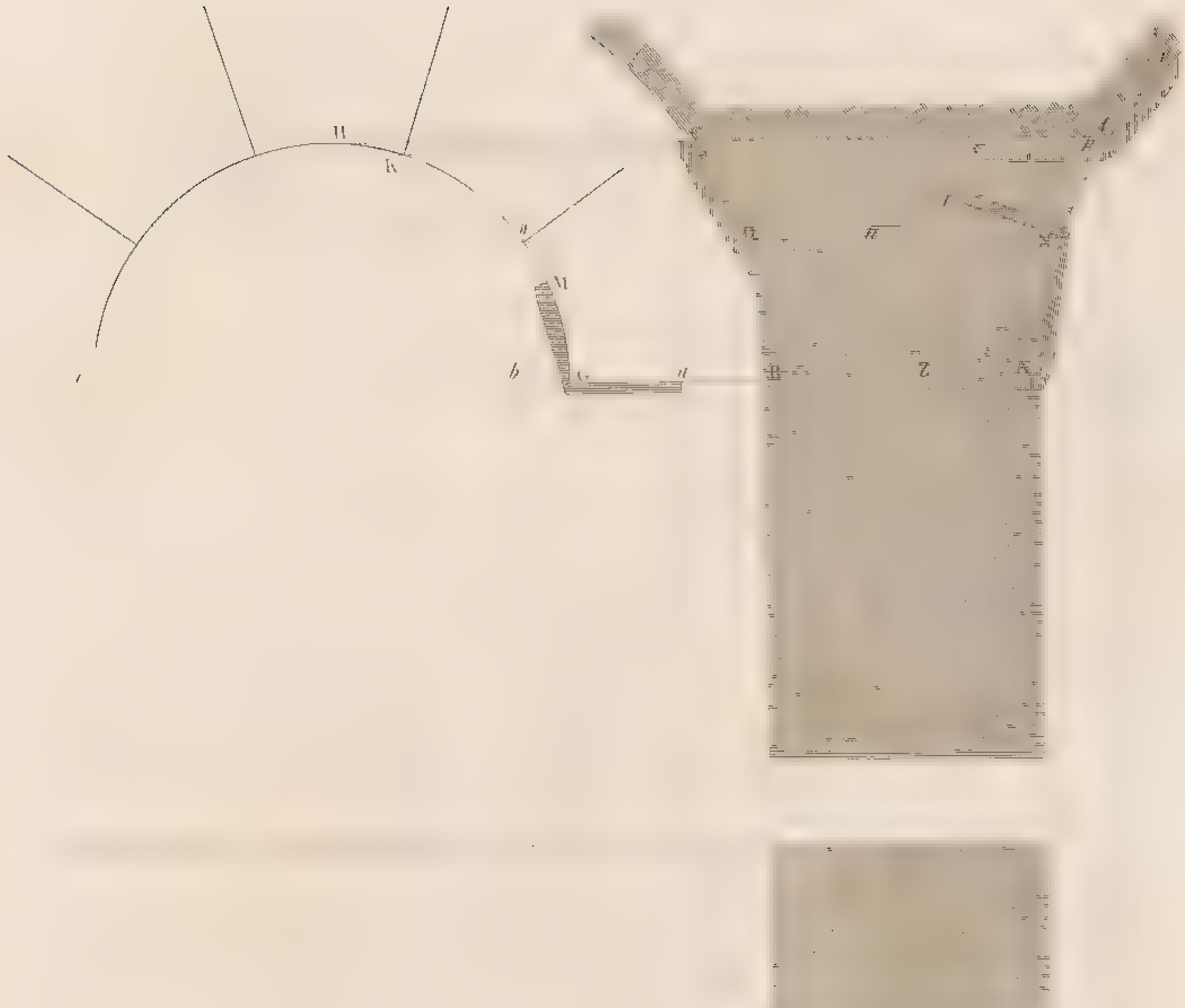
*To form the curve of intersection, and cut the stones for this arch.*—Let AB be the thickness of the wall in which the passage is to be made, BC and A*t* the two semi-circular arches; EL the opening of the passage; by which the arch GH*c* is described, which divide into any number of parts, at pleasure. Through the points of division draw the lines H*t*, K*p*, *w*N, which, with the semi-circular arches, will form mixt angles, that serve to give the heads of the stones the proper projection, to intersect the semi-circular vaults.

To mark in the plan, the meeting of the passage with the said semi-circular vaults, let fall the perpendiculars CO, SI, QR, &c., which, by their intersecting or meeting the lines RT, IV, OF, &c., will give the points R, I, O, &c., through which trace the curves POR and EFL.

To trace one of the first stones; square the bed and one side of a stone, take the thickness of the wall AB, which lay along the arris of the stone, and, at each of the said lines draw two others on the bed, square to the arris; with a bevel take the mixt angle ZAN, by which dress the two heads, square in themselves; on the upper bed trace the versed sine G *b*, and on the side the sine *bw*, then work out the sheeting with the curve G*w*, and cut the joints square to the sheeting curves; that is, the joint of the semi-circular vault by the mixt angle AN*r*, and that of the passage by the bevel MG *a*.

The other stones are cut exactly in the same manner, excepting that the bevel *n*QC is used to cut the sweep of the second stones, and the bevel *spv* for the key. The rest is so plain as to require no explanation.

# MASONRY.



Published 1 Dec 1824 by Thos. Kelly Paternoster Row

Engraved by R. Roffe

# MASONRY.

Engraved by R. Fenle

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An Archway revealed *and* splayed, *and the* splay arched *with a* Segment, *in order to give room for Gates to open when they are made to the height of the front Arch.* (*Plate* LXXXIII.)

See the elevation, (*figure* 1,) where A is the impost, BB the reveal, C the splayed retreat. Let ABDC, (*figure* 2,) be the plan, A*e* the depth of the impost, *efg* the reveal, *gc* the splay.

Describe the arch of the gate-head A′EB′, and that of the reveal *a′e′b′*; and, at the extremities C and D of the splay, draw the perpendiculars CF′ and DG′, in which find the points F and G in the following manner:

Describe the arch of the splay I′K′, (*fig.* 3,) make I′L′ equal to *g*C, (*fig.* 2.); perpendicular to I′L′ draw L′K′; make M′F′ and N′G′ each equal to L′K′, and through the points F′G′ trace the arc F′G′, as flat as may be necessary for the gates to swing open.

The most compounded joint in this gate is OP, formed by the arc of the reveal and that of the splay. To draw the joint-mould for this: from the point *h*, (*fig.* 2,) draw *h*Q′ perpendicular to AB, meeting O′P′ in Q′. Draw I′S′ perpendicular to IL, and Q′S′ and P′T parallel to IL′: join TS′ intersecting the arc in U′; draw U′V′ parallel to P′T, meeting the joint-line O′P′ in V′, and V′ is the point in which the stone will form an angle. Draw the line of the impost *ab*, and the reveal *bcd* (*fig.* 2); draw U′W′ perpendicular to I′L′, make *hi*, on the splay of the jamb, equal to IW′, and draw *ik* parallel to AB. Make *kl* equal to O′V′, *mn* equal to O′P′, join *dl*, *ln*, and *abcdln* will be the form of the joint; and all the joints which are cut in this forked angle are found in the same manner.

*For the mould of the second joint.*—Make *mp* equal to XY, and join *dp*.

*To cut one of the first stones.*—With the head-mould, B′O′P′I′, prepare an arch-stone, as No. 1, whose length is equal to *am* on the plan; apply the

mould of the plan, IA*efg*CK, on the under-bed, and, on the upper bed, the joint-mould, *zabcdlnx*. On the soffit of No. 1, draw a b, to mark the thickness of the impost, and, on the rear or tail of the stone, draw c *d*, representing N′P′ on the elevation. Then, to hollow out the concave surface of the reveal, with a curved bevel, *b′ l′*, (*fig.* 3,) draw the curves e f, g h, No. 1. By the lines, b c, c *d*, d k, dress that side which will be terminated by k h, making use of the curved templet cut by *b′ l′*, (*fig.* 3,) which apply, from time to time, till the forked-joint is formed, and the whole of the superfluous stone being cut away, it will appear in the form of No. 2.

The second stone, No. 3, is traced in the same manner.

## X.—RAKING MOULDINGS. (*Plate* LXXXIV.)

Raking Mouldings more frequently occur in Masonry than in Joinery: hence we give the following design in consistency with the plan of our work.

*Figure* 1 is a complete design of a cornice, having part of the ogee level, and part inclined, as happens in the level cornice of a building, with a pediment in the front: *a, b, c, d, e,* is the moulding at the angle of the break, or projecture, of the pediment, which moulding is given in order to find the right section of the inclined ogee in the pediment. Let *af* and *e* e be the two parallel lines which terminate the breadth of the raking or inclined moulding; and let *ak* and *el* be the parallel lines terminating the breadth of the moulding which is level.

At a convenient place draw *p t* parallel to the edge *a k* of the level ogee: In the given moulding, *a, b, c, d, e,* take any number of points, *b, c, d,* and draw *bg, ch, di,* parallel to *af,* or *e*e; also draw *ap, bq, cr, ds,* and *et,* perpendicular to *ak,* or *el,* meeting *pt* in the points *q, r, s:* also, at any convenient distance from *af,* draw *p′t′* parallel thereto, and transfer the distances *p q, q r, r s, s t,* to p′q′, q′r′, r′s′, and s′t′, and draw p′A, q′B, r′C, s′D, t′E,

# MASONRY.

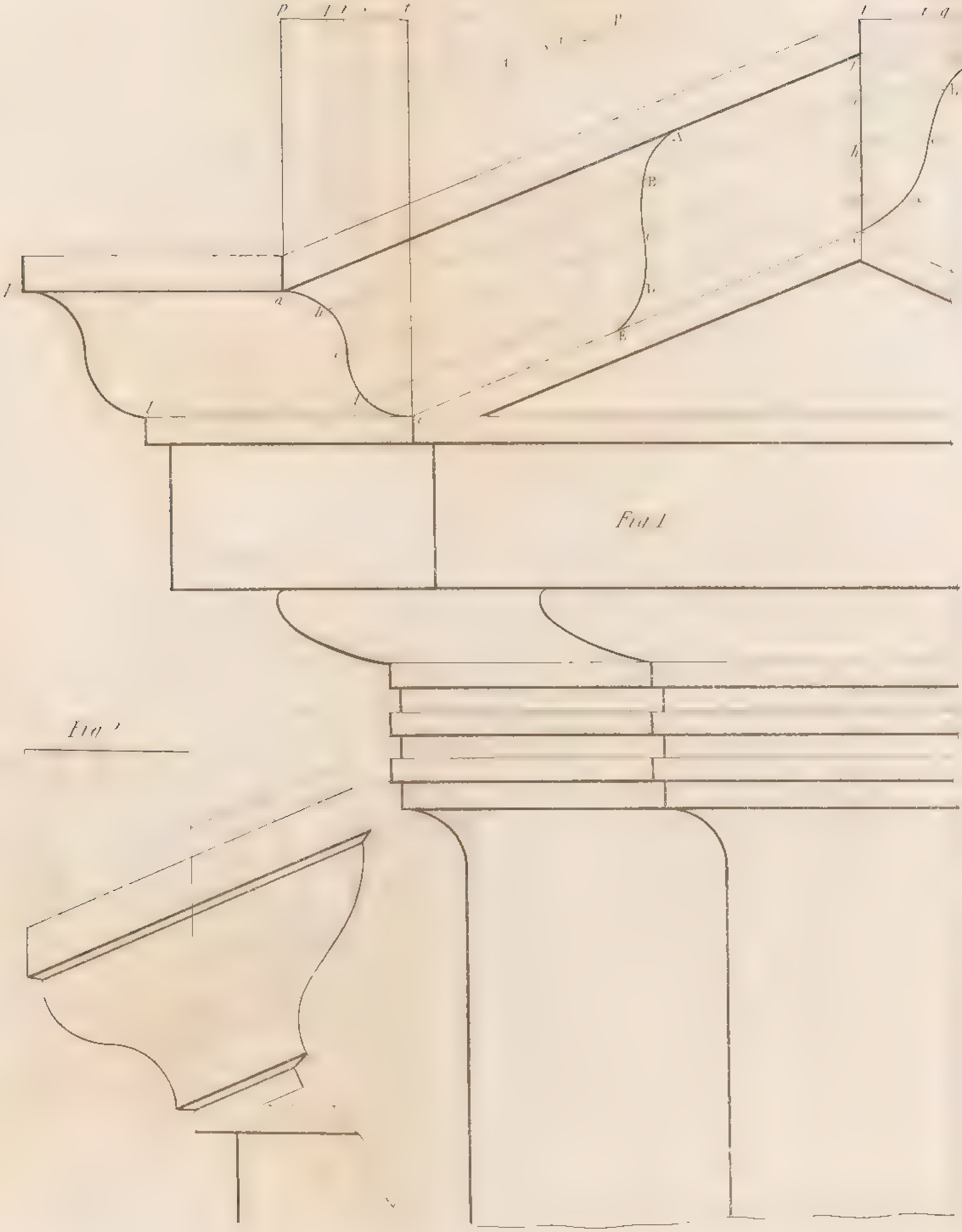



Fig. 1

Fig. 2

Engraved by R. Rotte.

[illegible]

perpendiculars to $t'p'$, or $af$, meeting the lines $af$, $bg$, $ch$, $di$, $e$e, in the points A, B, C, D, and E, and a curve, being drawn through these points, will be the right section of the raking-moulding.

*To find the section through mitre* $t''$e of the two inclined sides, draw $t''p''$ perpendicular to $t''$e, and transfer the distances $ts$, $sr$, $rq$, $qp$, to $t''s''$, $s''r''$, $r''q''$, $q''p''$. Draw s″d, r″c, q″b, p″a, perpendicular to t″p″, also draw $f$a, $q$b, $h$c, $i$d, perpendicular to $t''$e. Then the curve through the points a b c d e will be the common section of the two raking-mouldings, as required.

*Figure* 2 is a *reverse ogee,* which is traced on the same principle as the ogee, *figure* 1.

# CHAPTER VII.

## AN EXPLANATION OF TERMS, AND DESCRIPTION OF TOOLS, USED IN MASONRY; INCLUDING THE COMPOSITION OF CEMENTS, OR MORTAR, &c.

Abutment.—A term used both in carpentry and masonry. An explanation of it, as used in carpentry, may be found on referring to page 218. In masonry, the *abutments* of a bridge mean the walls adjoining to the land, which support the ends of the extreme arches or roadway.

Aperture.—An opening through a wall, &c. which has, generally, three straight sides; of these, two are perpendicular to the horizon, and the other parallel to it, connecting the lower ends of the vertical stones or *jambs.* The lower side is called the *cill,* and the upper side the *head.* The last is either an arch or a single stone. If it be an arch, the aperture is called an *arcade.* Apertures may be circular or cylindrical; but these are not very frequent.

Arch.—Part of a building suspended over a hollow, and concave towards the area of the same.

Archivolt *of the Arch of a Bridge.*—The curved line formed by the upper sides of the arch-stones in the face of the work; by the *archivolt* is also understood the whole set of arch-stones that appear in the face of the work.

Ashlar.—A term applied to common or free-stones, as they come out of the quarry. By *ashlar* is also meant the facing of squared stones on the front

of a building. If the work be so smoothed as to take out the marks of the tools by which the stones were first cut, it is called *plane-ashlar:* if figured, it may be *tooled ashlar,* or *random tooled,* or *chiselled,* or *boasted,* or *pointed.* If the stones project from the joints, it is said to be *rusticated.*

BANKER.—The stone bench on which work is cut and squared.

BANQUET.—The raised footway adjoining to the parapet on the sides of a bridge.

BATTARDEAU. See *Coffer-dam.*

BATTER.—The leaning part of the upper part of the face of a wall, which so inclines as to make the plumb-line fall within the base.

BEDS *of a Stone.*—The parallel surfaces which intersect the face of the work in lines parallel to the horizon.

In arching, the beds are, by some, called *summerings;* by others, with more propriety, *radiations* or *radiated joints.*

BOND.—That regular connection, in lapping the stones upon one another, when carrying up the work, which forms an inseparable mass of building.

BUTMENT. See *Abutment.*

CAISSON.—A chest of strong timber in which the piers of a bridge are built, by sinking it, as the work advances, till it comes in contact with the bed of the river, and then the sides are disengaged, being constructed for that purpose.

CEMENT *and* MORTAR, *Composition of.*—It is almost superfluous to say, that cement, or mortar, is a preparation of lime and sand, mixed with water, which serves to unite the stones, in the building of walls, &c.

On the proper or improper manner in which the cement or mortar is prepared and used, depends the durability and security of every building: we shall, therefore, here introduce many particulars on this head, discovered by *Dr. Higgins,* but which, not being generally known, have never been reduced into general practice.

For the preparation of every kind of mortar, or cement, the subsequent remarks should always be known. Of *Sand,* the following kinds are to be preferred; first, *drift-sand,* or *quarry-sand,* which consists chiefly of hard quartose flat-faced grains, with sharp angles; secondly, that which is the

freest, or may be most easily freed by washing, from clay, salts, and calcareous, gypseous, or other grains less hard and durable than quartz; thirdly, that which contains the smallest quantity of pyrites or heavy metallic-matter, inseparable by washing; and, fourthly, that which suffers the smallest diminution of its bulk in washing. Where a coarse and fine sand of this kind, and corresponding in the size of their grains with the coarse and fine sands hereafter described, cannot be easily procured, let such sand of the foregoing quality be chosen as may be sorted and cleansed in the following manner:—

Let the sand be sifted in streaming clear water, through a sieve which shall give passage to all such grains as do not exceed one-sixteenth of an inch in diameter; and let the stream of water, and the sifting, be regulated so that all the sand which is much finer than the Lynn-sand, commonly used in the London glass-houses, together with clay, and every other matter specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle, and the coarse rubbish and rubble remain on the sieve to be rejected.

Let the sand, which thus subsides in the receptacle, be washed in clean streaming water through a finer sieve, so as to be further cleansed, and sorted into two parcels; a coarser, which will remain in the sieve, which is to give passage to such grains of sand only as are less than one-thirtieth of an inch in diameter, and which is to be saved apart under the name of *coarse sand;* and a finer, which will pass through the sieve and subside in the water, and which is to be saved apart under the name of *fine sand.* Let the coarse and the fine sand be dried separately, either in the sun, or on a clean iron-plate, set on a convenient surface, in the manner of a sand-heat.

Let *stone-lime* be chosen, which heats the most in slaking, and slakes the quickest when duly watered; that which is the freshest made and closest kept; that which dissolves in distilled vinegar with the least effervescence, and leaves the smallest residue insoluble, and in the residue the smallest quantity of clay, gypsum, or martial matter. Let the lime, chosen accord-

ing to these rules, be put in a brass-wired sieve, to the quantity of fourteen pounds. Let the sieve be finer than either of the foregoing; the finer the better it will be: let the lime be slaked, by plunging it into a butt filled with soft-water, and raising it out quickly, and suffering it to heat and fume; and, by repeating this plunging and raising alternately, and agitating the lime until it be made to pass through the sieve into the water; and let the part of the lime which does not easily pass through the sieve be rejected: and let fresh portions of the lime be thus used, until as many ounces of lime have passed through the sieve as there are quarts of water in the butt.

Let the water, thus impregnated, stand in the butt closely covered until it becomes clear, and through wooden cocks, placed at different heights in the butt, let the clear liquor be drawn off, as fast and as low as the lime subsides, for use. This clear liquor is called *lime-water*. The freer the water is from saline matter, the better will be the cementing liquor made with it.

Let fifty-six pounds of the aforesaid chosen lime be slaked, by gradually sprinkling the lime-water on it, and especially on the unslaked pieces, in a close clean place. Let the slaked part be immediately sifted through the last mentioned fine brass-wired sieve: let the lime which passes be used instantly, or kept in air-tight vessels; and let the part of the lime which does not pass through the sieve be rejected. This finer and richer part of the lime, which passes through the sieve, may be called *purified lime*.

Let bone-ash be prepared in the usual manner, by grinding the whitest burnt bones; but let it be sifted, so as to be much finer than the bone-ash commonly sold for making cupels.

The best materials for making the cement being thus prepared, take fifty-six pounds of the coarse sand, and forty-two pounds of the fine sand; mix them on a large plank of hard wood placed horizontally; then spread the sand so that it may stand to the height of six inches, with a flat surface on the plank, wet it with the lime-water, and let any superfluous quantity of the liquor, which the sand in the condition described cannot retain, flow away off the plank. To the wettest sand add fourteen pounds of the purified lime, in several successive portions; mixing and beating them up together,

in the mean time, with the instruments generally used in making fine mortar: then add fourteen pounds of the bone-ash, in successive portions, mixing and beating all together.

The quicker and the more perfectly these materials are mixed and beaten together, and the sooner the cement thus formed is used, the better it will be. This may be called *coarse-grained water-cement*, which is to be applied in building, pointing, plastering, stuccoing, or other work, as mortar and stucco generally are; with this difference chiefly, that, as this cement is shorter than mortar, or common stucco, and dries sooner, it ought to be worked expeditiously in all cases; and, in stuccoing, it ought to be laid on by sliding the trowel upwards on it. The materials used along with this cement in building, or the ground on which it is to be laid in stuccoing, ought to be well wetted with the lime-water in the instant of laying on the cement. The lime-water is also to be used when it is necessary to moisten the cement, or when a liquid is required to facilitate the floating of the cement.

When such cement is required to be of a still finer texture, take ninety-eight pounds of the fine sand, wet it with the lime-water, and mix it with the purified lime and the bone-ash, in the quantities and in the manner above described; with this difference only, that fifteen pounds of lime, or thereabouts, are to be used instead of fourteen pounds, if the greater part of the sand be as fine as Lynn sand. This may be called *fine-grained water-cement.* It is used in giving the last coating, or the finish, to any work intended to imitate the finer-grained stones or stucco. But it may be applied to all the uses of the *coarse-grained water-cement*, and in the same manner.

When, for any of the foregoing purposes of pointing, building, &c., a cement is required much cheaper and coarser-grained than either of the foregoing, then much coarser clean sand than the foregoing coarse sand, or well-washed fine rubble, is to be provided. Of this coarse sand, or rubble, take fifty-six pounds, of the foregoing coarse sand twenty-eight pounds, and of the fine sand fourteen pounds; and, after mixing these, and wetting them with the cementing-liquor, in the foregoing manner, add fourteen pounds, or

somewhat less, of the purified lime, and then fourteen pounds, or somewhat less, of the bone-ash, mixing them together in the manner already described. When the cement is required to be white, white sand, white lime, and the whitest bone-ash, are to be chosen. Gray sand, and gray bone-ash formed of half-burnt bones, are to be chosen to make cement gray; and any other colour of the cement is obtained, either by choosing coloured sand, or by the admixture of the necessary quantity of coloured talc in powder, or of coloured, vitreous, or metallic, powders, or other durable colouring ingredients, commonly used in paint.

This water-cement, whether the coarse or fine-grained, is applicable in forming artificial stone, by making alternate layers of the cement and of flint, hard stone, or bricks, in moulds of the figure of the intended stone, and by exposing the masses so formed to the open air, to harden.

When such cement is required for water fences, two-thirds of the prescribed quantity of bone-ashes are to be omitted; and, in the place thereof, an equal measure of powdered terras is to be used; and, if the sand employed be not of the coarsest sort, more terras must be added, so that the terras shall be one-sixth part of the weight of the sand.

When such a cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush, flint-powder, or the powder of any quartose or hard earthy substance, may be used in the place of sand; but in a quantity smaller, in proportion as the flint or other powder is finer; so that the flint-powder, or other such powder, shall not be more than six times the weight of the lime, nor less than four times its weight. The greater the quantity of lime within these limits, the more will the cement be liable to crack by quick drying, and, *vice versâ.*

Where the above described sand cannot be conveniently procured, or where the sand cannot be conveniently washed and sorted, that sand which most resembles the mixture of coarse and fine sand above prescribed, may be used as directed, provided due attention be paid to the quantity of the lime, which is to be greater as the quality is finer, and, *vice versâ.*

Where sand cannot be easily procured, any durable stony body, or baked earth, grossly powdered, and sorted nearly to the sizes above prescribed for sand, may be used in the place of sand, measure for measure, but not weight for weight, unless such gross powder be specifically as heavy as sand.

Sand may be cleansed from every softer, lighter, and less durable, matter, and from that part of the sand which is too fine, by various methods preferable in certain circumstances, to that which has been already described.

Water may be found naturally free from fixable gas, selenite, or clay; such water may, without any great inconvenience, be used in the place of the lime-water; and water approaching this state will not require so much lime as above prescribed to make the lime-water; and a lime-water sufficiently useful may be made by various methods of mixing lime and water in the described proportions, or nearly so.

When stone-lime cannot be procured, chalk-lime, or shell-lime, which best resembles stone-lime, in the foregoing characters of lime, may be used in the manner described, excepting that fourteen pounds and a half of chalk-lime will be required in the place of fourteen pounds of stone-lime. The proportion of lime, as prescribed above, may be increased without inconvenience, when the cement of stucco is to be applied where it is not liable to dry quickly; and, in the contrary case, this proportion may be diminished. The defect of lime, in quantity or quality, may be very advantageously supplied, by causing a considerable quantity of lime-water to soak into the work, in successive portions, and at distant intervals of time; so that the calcareous matter of the lime-water, and the matter attracted from the open air, may fill and strengthen the work.

The powder of almost every well-dried or burnt animal substance may be used instead of bone-ash; and several earthy powders, especially the micaceous and the metallic; and the elixated ashes of divers vegetables, whose earth will not burn to lime, as well as the ashes of mineral fuel, which are of the calcareous kind, but will not burn to lime, will answer the ends of bone-ash in some degree.

The quantity of bone-ash described may be lessened without injuring the cement; in those circumstances especially which admit the quantity of lime to be lessened, and in those wherein the cement is not liable to dry quickly. The art of remedying the defects of lime may be advantageously practised to supply the deficiency of bone-ash, especially in building, and in making artificial stone with this cement.

As the preceding method of making mortar differs, in many particulars, from the common process, it may be useful to enquire into the causes on which this difference is founded.

When the sand contains much clay, the workmen find that the best mortar they can make must contain about one-half lime; and hence they lay it down as certain, that the best mortar is made by the composition of half sand and half lime.

But with sand requiring so great a proportion of lime as this, it will be impossible to make good cement; for it is universally allowed that the hardness of mortar depends on the crystallization of the lime round the other materials which are mixed with it; and thus uniting the whole mass into one solid substance. But, if a portion of the materials used be clay, or any other friable substance, it must be evident that, as these friable substances are not changed in one single particular, by the process of being mixed up with lime and water, the mortar, of which they form a proportion, will consequently be, more or less, of a friable nature, in proportion to the quantity of friable substances used in the composition of the mortar. On the other hand, if mortar be composed of lime and good sand only, as the sand is a stony substance, and not in the least friable, and as the lime, by perfect crystallization, becomes likewise of a stony nature, it must follow, that a mass of mortar, composed of these two stony substances, will itself be a hard, solid, unfriable, substance. This may account for one of the essential variations in the preceding method from that in common use, and point out the necessity of never using, in the place of sand, which is a durable stony body, the scrapings of roads, old mortar, and other rubbish, from antient

buildings, which are frequently made use of, as all of them consist, more or less, of muddy, soft, and minutely divided particles.

Another essential point is the nature and quality of the lime. Now, experience proves that, when lime has been long kept in heaps, or untight casks, it is reduced to the state of chalk, and becomes every day less capable of being made into good mortar; because, as the goodness or durability of the mortar depends on the crystallization of the lime, and, as experiments have proved, that lime, when reduced to this chalk-like state, is always incapable of perfect crystallization, it must follow that, as lime in this state never becomes crystallized, the mortar of which it forms the most indispensable part, will necessarily be very imperfect; that is to say, it will never become a solid stony substance; a circumstance absolutely required in the formation of good durable mortar. These are the two principal ingredients in the formation of mortar; but, as water is also necessary, it may be useful to point out that which is the fittest for this purpose; the best is rain-water, river-water the second, land-water next, and spring-water last.

The ruins of the antient Roman buildings are found to cohere so strongly, as to have caused an opinion that their constructors were acquainted with some kind of mortar, which, in comparison with ours, might justly be called *cement;* and that, to our want of knowledge of the materials they used, is owing the great inferiority of modern buildings in their durability. But a proper attention to the above particulars would soon show that the durability of the antient edifices depended on the manner of preparing their mortar more than on the nature of the materials used. The following observations will, we think, prove this beyond a possibility of doubt:

Lime, which has been slaked and mixed with sand, becomes hard and consistent when dry, by a process similar to that which produces natural *stalactites* in caverns. These are always formed by water dropping from the roof. By some unknown and inexplicable process of nature, this water has had dissolved in it a small portion of calcareous matter, in a caustic state. So long as the water continues covered from the air, it keeps the earth dissolved

in it; it being the natural property of calcareous earths, when deprived of their fixed air, to dissolve in water. But, when the small drop of water comes to be exposed to the air, the calcareous matter contained in it begins to attract the fixable part of the atmosphere. In proportion as it does so, it also begins to separate from the water, and to re-assume its native form of lime-stone or marble. When the calcareous matter is perfectly crystallized in this manner, it is to all intents and purposes lime-stone or marble of the same consistence as before. If lime, in a caustic state, is mixed with water, part of the lime will be dissolved, and will also begin to crystallize. The water which parted with the crystallized lime will then begin to act upon the remainder, which it could not dissolve before; and thus the process will continue, either till the lime be all reduced to an *effete,* or crystalline state, or something hinders the action of the water upon it. It is this crystallization which is observed by the workmen when a heap of lime is mixed with water, and left for some time to macerate. A hard crust is formed upon the surface, which is ignorantly called *frostling*, though it takes place in summer as well as in winter. If, therefore, the hardness of the lime, or its becoming a cement, depends entirely on the formation of its crystals, it is evident that the perfection of the cement must depend on the perfection of the crystals, and the hardness of the matters which are entangled among them. The additional substances used in making of mortar, such as sand, brick-dust, or the like, serve only for a purpose similar to what is answered by sticks put into a vessel full of any saline solution; namely, to afford the crystals an opportunity of fastening themselves upon it. If, therefore, the matter interposed between the crystals of the lime is of a friable brittle nature, such as brick-dust or chalk, the mortar will be of a weak and imperfect kind; but, when the particles are hard, angular, and very difficult to be broken, such as those of river or pit-sand, the mortar turns out exceedingly good and strong. That the crystallization may be the more perfect, a large quantity of water should be used, the ingredients be perfectly mixed together, and the drying be as slow as possible. An attention to these particulars would make the buildings of the moderns equally durable with those of the antients. In the

old Roman works, the great thickness of the walls necessarily required a vast length of time to dry. The middle of them was composed of pebbles thrown in at random, and which, evidently, had thin mortar poured in among them. Thus a great quantity of the lime would be dissolved, and the crystallization performed in the most perfect manner. The indefatigable pains and perseverance, for which the Romans were so remarkable in all their undertakings, leave no room to doubt that they would take care to have the ingredients mixed together as well as possible. The consequence of all this is, that the buildings formed in this manner are all as firm as if cut out of a solid rock; the mortar being equally hard, if not more so, than the stones themselves.

Centres.—The frame of timber-work for supporting arches during their erection.

Coffer-dam, or Battardeau.—A case of piling, without a bottom, constructed for inclosing and building the piers of a bridge. A coffer-dam may be either single or double, the space between being filled with clay or chalk, closely rammed.

Drag.—A thin plate of steel indented on the edge, like the teeth of a saw, and used in working soft stone, which has no grit, for finishing the surface.

Drift.—The horizontal force of an arch, by which it tends to overset the piers.

Extrados *of an Arch.*—The exterior or convex curve, or the top of the arch-stones. This term is opposed to the *Intrados,* or concave side.

Extrados *of a Bridge.*—The curve of the road-way.

Fence-Wall.—A wall used to prevent the encroachment of men or animals.

Footings.—Projecting courses of stone, without the naked superincumbent part, and which are laid in order to rest the wall firmly on its base.

Hammer.—See *Tools.*

Headers.—Stones disposed with their length horizontally, in the thickness of the wall.

Jettee.—The border made around the stilts under a pier.

Impost or Springing.—The upper part or parts of a wall employed for springing an arch.

Intrados.—See *Extrados.*

Joggled Joints.—The method of indenting the stones, so as to prevent the one from being pushed away from the other by lateral force.

Key-Stones.—A term frequently used for *bond-stones.*

Key-Stone.—The middle voussoir of an arch, over the centre.

Key-Stone *of an Arch.*—The stone at the summit of the arch, put in last for wedging and closing the arch.

Level.—Horizontal, or parallel to the horizon.

Mallet.—See *Tools.*

Mortar.—See *Cement.*

Naked, *of a Wall.*—The vertical or battering surface, whence all projectures arise.

Off-Set.—The upper surface of a lower part of a wall, left by reducing the thickness of the superincumbent part upon one side or the other, or both.

Point.—See *Tools.*

Parapets.—The breast-walls erected on the sides of the extrados of the bridge, for preventing passengers from falling over.

Paving.—A floor, or surface of stone, for walking upon.

Piers *in Houses.*—The walls between apertures, or between an aperture and the corner.

Piers *of a Bridge.*—The insulated parts between the apertures or arches, for supporting the arches and road-way.

Piles.—Timbers driven into the bed of a river, or the foundation of a building for supporting a structure.

Pitch *of an Arch.*—The height from the springing to the summit of the arch.

Push *of an Arch.*—The same as *Drift;* which see.

Quarry.—The place whence stones are raised.

Random Courses, *in Paving.*—Unequal courses, without any regard to equi-distant joints.

Saw.—See *Tools.*

Shoot *of an Arch.*—The same as *Drift;* which see.

Span.—The span of an arch is its greatest horizontal width.

Sterlings.—A case made about a pier of stilts in order to secure it. See the following article.

Stilts.—A set of piles driven into the bed of a river, at small distances, with a surrounding case of piling driven closely together, and the interstices filled with stones, in order to form a foundation for building the pier upon.

Straight-Edge.—See *Tools.*

Stretchers.—Those stones, which have their length disposed horizontally in the length of the wall.

Through Stones.—A term employed, in some countries, for bond-stones.

Thrust.—The same as *Drift;* which see.

Tools *used by Masons.*—The masons' *Level, Plumb-Rule, Square, Bevel, Trowel, Hod, and Compasses,* are similar in every respect to those tools which bear the same name among bricklayers; and which are described hereafter. Those tools, which differ from such as are used by the bricklayer, are as follow:—

The *Saw* used by masons is without teeth, and stretched in a frame nearly resembling the joiner's saw-frame. It is made from four to six feet, or more, in length, according to the size of the slabs, which are intended to be cut by it. To facilitate the process of cutting slabs into slips and scantlings, a portion of sharp silicious sand is placed upon an inclined plane, with a small barrel of water at the top, furnished with a spiggot, which is left sufficiently loose to allow the water to exude drop by drop; and thus, by running over the sand, carries with it a portion of sand into the kerf of the stone. The workman sits at one side of the stone, and draws the saw to and fro, horizontally, taking a range of about twelve inches each time before he returns. By this means, calcareous stones of the hardest kinds may be cut into slabs of any thickness, with scarcely any loss of substance. But, as this method of sawing stone is slow and expensive, mills have been erected in various parts of Great Britain, by which the same process is performed at a

much cheaper rate, and in some of these mills every species of moulding upon stone is produced.

Masons make use of many *chisels*, of different sizes, but all resembling, or nearly resembling, each other in form. They are usually made of iron and steel welded together; but, when made entirely of steel, which is more elastic than iron, they will naturally produce a greater effect with any given impulse. The form of masons' chisels is that of a wedge, the cutting-edge being the vertical angle. They are made about eight or nine inches long. When the cutting-edge is broader than the portion held in the hand, the lower part is expanded in the form of a dove-tail. When the cutting-edge is smaller than the handle, the lower end is sloped down in the form of a pyramid. In finishing off stone, smooth and neat, great care should be taken that the arris is not splintered, which would certainly occur, if the edge of the chisel were directed outwards in making the blow: but, if it be directed inwards, so as to overhang a little, and form an angle of about forty-five degrees, there is little danger of splintering the arris in chipping.

Of the two kinds of chisels, which are the most frequently made use of, *the tool* is the largest; that is to say, in the breadth of its cutting-edge; it is used for working the surface of stone into narrow furrows, or channels, at regular distances; this operation is called *tooling*, and the surface is said to be *tooled*.

The *Point* is the smallest kind of chisel used by masons, being never more than a quarter of an inch broad on its cutting-edge. It is used for reducing the irregularity of the surface of any rough stone.

The *Straight-Edge* is similar to the instrument among carpenters of the same name; it being a thin board, planed true, to point out cross-windings and other inequalities of surface, and thus direct the workmen in the use of the chisel.

The *Mallet* used by the mason differs from that of any other artisan. It is similar to a bell in contour, excepting a portion of the broadest part, which is rather cylindrical. The handle is rather short, being only just long enough to be firmly grasped in the hand. It is employed for giving percus-

sive force to chisels, by striking them with any part of the cylindrical surface of the mallet.

*The Hammer* used by masons is generally furnished with a point or an edge like a chisel. Both kinds are used for dividing stones, and likewise for producing those narrow marks or furrows left upon hewn-stone work which is not ground on the face.

VAULT.—A mass of stones so combined as to support each other over a hollow.

UNDER BED *of a Stone.*—The lower surface, generally placed horizontally.

UPPER BED *of a Stone.*—The upper surface, generally placed horizontally.

VOUSSOIRS.—The arch-stones in the face or faces of an arch; the middle one is called the *key-stone.*

WALL.—An erection of stone, generally perpendicular to the horizon; but sometimes *battering,* in order to give stability.

WALLS, *Emplection.*—Those which are built in regular courses, with the stones smoothed in the face of the work. They are of two kinds, Roman and Grecian, as already noticed. The difference is, that the core of the Roman emplection is rubble; whereas in the Grecian emplection, it is built in the same manner as the face, and every alternate stone goes through the entire thickness of the wall. *See pages* 306, 307.

*Walls, Isodomum;* those wherein the courses are of equal thickness, compact, and regularly built; but the stones are not smoothed on the face.

*Walls, Pseudo-Isodomum;* those which have unequal courses. *See page* 306.

# CHAPTER VIII.

## BRICKLAYING:

INCLUDING AN ABSTRACT OF THE BUILDING ACT, 14th Geo. III. c. 78.

Bricklaying is the art of Building with Bricks, or of uniting them, by cement or mortar, into various forms for particular purposes.

The bricks of the antients were of various forms and sizes, and their triangular bricks were peculiarly adapted to certain figures, but modern bricks, of English make, are commonly of one form, 9 inches long, by $4\frac{1}{2}$ broad, and $2\frac{1}{2}$ deep.

Bricks are made of a species of clay or loamy earth, either pure or with various mixtures; they are shaped in a mould, and, after some drying in the sun or air, are burnt to a hardness. The more pure the earth of which it is formed, the harder and firmer the brick will be. The bricks generally known to our modern builders are of several sorts: that is to say, *Marls*, of two qualities, *Gray-Stocks*, and *Place-Bricks*, besides two or three foreign kinds, occasionally imported. Bricks vary in quality, according to the quality of the material of which they are composed, the manner in which the clay is tempered, and the diffusion of the heat while burning.

The finest kind of Marls, called *Firsts*, are those usually selected for arches over doors and windows: those less fine, called *Seconds*, are commonly used for the fronts of buildings. The Gray-Stocks are of the next quality, and are generally of a good earth, well wrought, with little mixture, sound, and durable. Place-Bricks are too frequently poor and brittle, badly

burnt, and of very irregular colour. *Burrs* or *Clinkers* are such as are so much overburnt as to vitrify, and run two or three together.

*Red Stocks* and the *Red Bricks,* called also, from their use, *Cutting Bricks,* owe their colour to the nature of the clay of which they are made; this is always used tolerably pure, and the bricks of the better kind are called by some *Clay Bricks,* because they are supposed to be made of nothing else.

The Gray Stocks, being made of a good earth, well wrought, are commonly used in front in building: the Place Bricks being made of clay, with a mixture of dirt and other coarse materials, and more carelessly put out of hand, are therefore weaker and more brittle, and are introduced where they cannot be seen, and where little stress is laid upon them: the Red Bricks, of both kinds, are made of a particular earth, well wrought, and little injured by mixtures; and they are used in fine work, in ornaments over windows, and in paving. These are frequently cut or ground down to a perfect evenness, and sometimes set in putty instead of mortar; and thus set they make a very beautiful appearance.

These are the kinds of bricks commonly used by us in building, and their difference is owing to variety in the materials. The Place Bricks and Gray Stocks are made in the neighbourhood of London, wherever there is a brick-work; the two kinds of red brick, depending upon a particular kind of earth, can be made only where that is to be had; they are furnished from several places within fifteen or twenty miles of London.

We have already observed, that there are two or three other kinds of brick to be named, which are imported from other countries; and there is also one of the red or cutting brick sort, that is of our own manufacture, and for its excellence deserves to be particularly mentioned; this is the Hedgerly Brick: it is made at a village of that name, of the famous earth called Hedgerly loam, well-known to the glass-makers and chymists. The loam is of a yellow-reddish colour, and very harsh to the touch, containing a great quantity of sand; its particular excellence is, that it will bear the greatest violence of fire without injury: the chymists coat and lute their furnaces with this, and the ovens at glass-houses are also repaired or lined with it,

where it stands all the fury of their heat without damage. It is brought into London for this purpose, under the name of Windsor loam, the village being near Windsor, and is sold at a high price. The bricks made of this are of the finest red that can be imagined. They are called ***Fire-Bricks,*** because of their enduring the fire; and are used about furnaces and ovens in the same way as the earth.

The foreign bricks above mentioned are the ***Dutch*** and ***Flemish Bricks*** and *Clinkers:* these are all nearly of a kind, and are often confounded together; they are very hard, and of a dirty brimstone colour; some of them not much unlike our Gray Stocks, others yellower. The Dutch are generally the best baked, and Flemish the yellowest. As to the Clinkers, they are the most baked of all, and are generally warped by the heat. These bricks are used for peculiar purposes; the Dutch and Flemish for paving yards, stables, and the like; and the clinkers for ovens.

The fine red cutting English Bricks are twice, or more than twice, the price of the best Gray Stocks; the Red Stocks half as dear again as the gray; and the Place Bricks, as they are much worse, so they are much cheaper, than any of the others.

The Gray Stocks and Place Bricks are employed in the better and worse kinds of plain work; the red stocks, as well as the gray, are used sometimes in this business, and sometimes for arches, and other more ornamental pieces: the fine red cutting bricks are used for ruled and gauged work, and sometimes for paving; but the red stones are more frequently employed when a red kind is required for this purpose.

The Red Cutting Brick, or fine red, is the finest of all bricks. In some places they are not at all acquainted with this; in others, they confound it with the red stock, and use that for it; though, where the fine red brick is to be had pure and perfectly made, the difference is five to three in the sale price between that and the red stock.

The Red and Gray Stock are frequently put in gauged arches, and one as well as the other set in putty instead of mortar: this is an expensive work,

but it answers in beauty for the regularity of the disposition and fineness of the joints, and has a very pleasing effect.

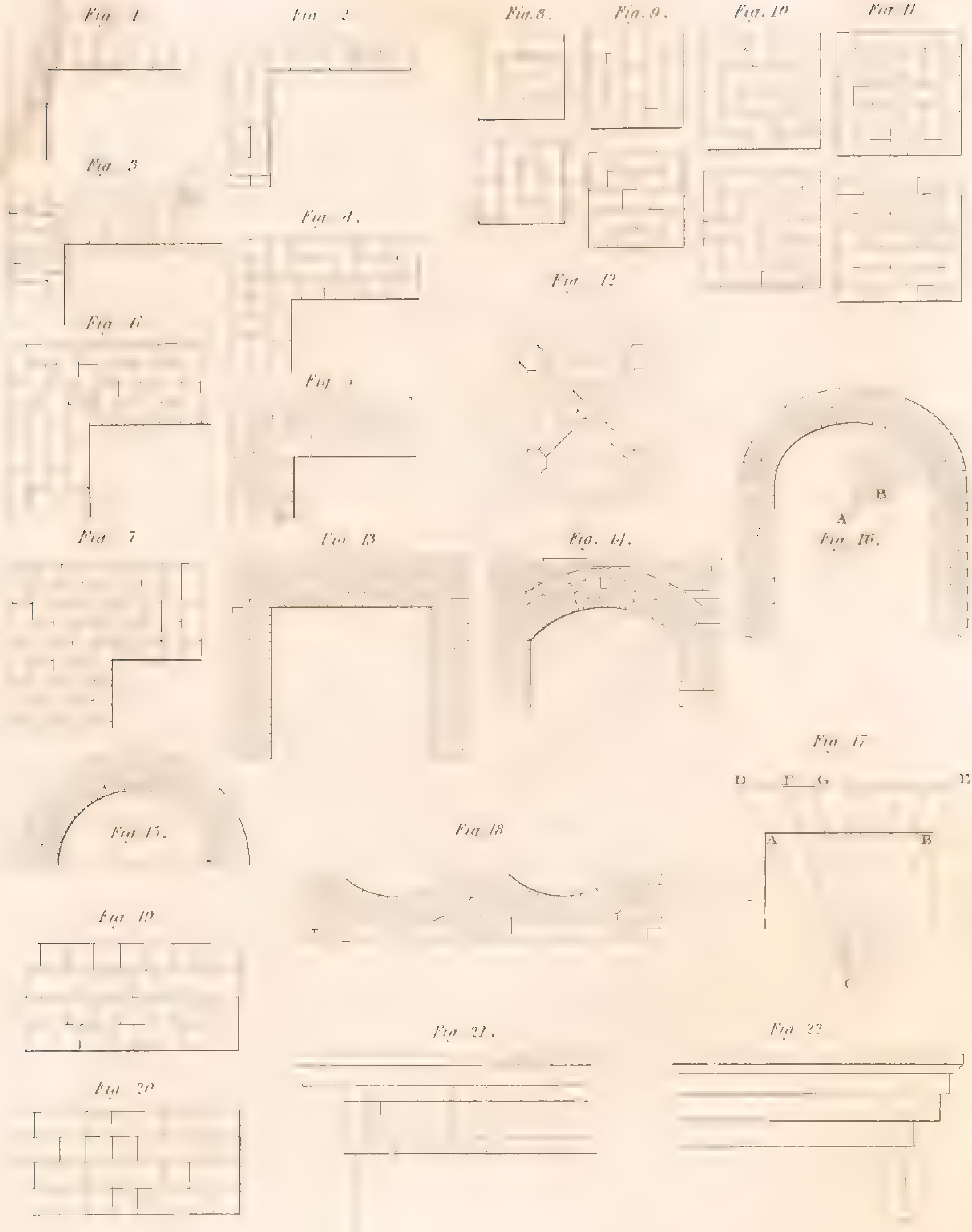
The fine Red Brick is used in arches ruled and set in putty in the same manner; and, as it is much more beautiful, is somewhat more costly. This kind is also the most beautiful of all in cornices, ruled in the same manner, and set in putty.

The Gray Stocks of an inferior kind are also used in brick walls.

The Place Bricks are used in paving dry, or laid in mortar, and they are put down flat or edgewise. If they are laid flat, thirty-two of them pave a square yard; but, if they are placed edgewise, it takes twice that number: in the front work of walls the Place-Bricks should never be admitted, even in the meanest building. That consideration, therefore, only takes place in the other kinds: and the fine Cutting Bricks come so very dear this way, that few people will be brought to think of them; so that it lies, in a great measure, between the Gray Stocks and Red Stocks. Of these the gray are most used; and this not only because they are cheaper, but, in most cases where judgement is preferred to fancy, they will have the preference.

We see many very beautiful pieces of workmanship in Red Brick; but this should not tempt the judicious architect to admit them into the front walls of buildings. In the first place, the colour itself is fiery and disagreeable to the eye; and, in summer, it has an appearance of heat that is very disagreeable; for this reason it is most improper in the country, though the oftenest used there, from the difficulty of getting gray. But a farther consideration is, that, in the fronts of most important buildings, there is more or less stone-work; now, as there should be as much conformity as can be attained between the general nakedness of the wall and those several ornaments which project from it; the nearer they are of a colour, the better they always range together; and if we cast our eyes upon two houses, the one of red, and the other of gray brick, where there is a little stone-work, we shall not be a moment in doubt which to prefer. There is something harsh in the transition from the red brick to stone, and it seems altogether unnatural;

# BRICKLAYING.



in the other, the Gray Stocks come so near the colour of stone, that the change is less violent, and they sort better together. Hence, also, the Gray Stocks are to be considered as best coloured when they have least of the yellow cast; for the nearer they come to the colour of stone, when they are to be used together with it, it is certainly the better. Where there is no stone-work, there generally is wood; and this, being painted white, as is commonly the practice, has yet a greater effect with red brick than the stone-work: the transition is more sudden in this than in the other; but, on the other hand, in the mixture of gray bricks and white paint, the colour of the brick being soft, there is no violent change.

The Gray Stocks are now made, of prime quality, in the neighbourhood of London. The late Duke of Norfolk had the bricks brought from his estate, in that county, for building the front of his house, in St. James's-square; but the event shews that his Grace might have been better supplied near at hand, as to colour, with equal hardness.

The greatest advantage that a Gray Stock, which is the standard brick, can have, is in its sound body and pale colour; the nearer it comes to stone the better; so that the principal thing the brick-maker ought to have in view, for the improvement of his profession, is the seeking for earth that will burn pale, and that will have a good body, and to see it has sufficient working. The judicious builder will always examine his bricks in this light, and be ready to pay that price which is merited by the goodness of the commodity.

The utility and common practice of building all our edifices of brick, both in London and the country, arises from motives too obvious to need a definition; since it is generally considered to be much the cheapest, as well as the most eligible substance that can be invented for the purpose, both in point of beauty and duration, and inferior to nothing but wrought stone.

Bricks are laid in a varied, but regular, form of connection, or *Bond*, as exhibited in *Plate* LXXXV. The mode of laying them for a 9-inch walling, shown in *figure* 1, being denominated *English Bond;* and *figure* 2, *Flemish Bond. Figure* 3 is English Bond, in a brick and a half, or 14-inch walling;

and *figure* 4, Flemish Bond, in the same. *Figure* 5 represents another method of disposing Flemish Bond in a 14-inch wall. *Figure* 6, English Bond, in an 18-inch, or two brick thick, wall; and *figure* 7, English Bond, in a two and half brick thick wall.

*Figures* 8, 9, 10, 11, represent square courses, in pairs, of Flemish Bond. In each pair, if one be the lower course, the other will be the upper course.

The Bricks, having their lengths in the thickness of the wall, are termed *Headers,* and those which have their lengths in the length of the wall are *Stretchers.* By a *Course,* in walling, is meant the bricks contained between two planes parallel to the horizon, and terminated by the faces of the wall. The thickness is that of one brick with mortar. The mass formed by bricks laid in concentric order, for arches or vaults, is also denominated a *Course.*

The disposition of bricks in a wall, of which every alternate course consists of *headers,* and of which every course between every two nearest courses of headers consist of *stretchers,* constitutes *English Bond.*

The disposition of bricks, in a wall, (except at the quoins,) of which every alternate brick in the same course is a *header,* and of which every brick between every two nearest headers is a *stretcher,* constitutes *Flemish Bond.*

It is, therefore, to be understood that *English Bond* is a continuation of one kind throughout, in the same course or horizontal layer, and consists of alternate layers of headers and stretchers, as shown in the plate; the headers serving to bind the wall together, in a longitudinal direction, or lengthwise, and the stretchers to prevent the wall splitting crosswise, or in a transverse direction. Of these evils the first is of the worst kind, and therefore the most to be feared.

A respectable writer on this subject has said, that the old English mode of brick-work affords the best security against such accidents; as work of this kind, wheresoever it is so much undermined as to cause a fracture, is not subject to such accidents, but separates, if at all, by breaking through the solid brick, just as if the wall were composed of one piece.

The antient brick-work of the Romans was of this kind of bond, but the existing specimens of it are very thick, and have three, or sometimes more,

courses of brick, laid at certain intervals of the height, stretchers on stretchers, and headers on headers, opposite the return wall, and sometimes at certain distances in the length, forming piers, that bind the wall together in a transverse direction; the intervals between these piers were filled up, and formed panels of rubble or reticulated work;* consequently great substance, with strength, were economically obtained.

It will, also, be understood that *Flemish Bond* consists in placing, in the same course, alternate headers and stretchers, a disposition considered as decidedly inferior in every thing but appearance, and even in this the difference is trifling; yet, to obtain it, strength is sacrificed, and bricks of two qualities are fabricated for the purpose; a firm brick often rubbed and laid in what the workmen term a putty-joint for the exterior, and an inferior brick for the interior, substance of the wall; but, as these did not correspond in thickness, the exterior and interior surface of the wall would not be otherwise connected together than by an outside heading brick, here and there continued of its whole length; but, as the work does not admit of this at all times, from the want of agreement in the exterior and interior courses, these headers can be introduced only where such a correspondence takes place, which, sometimes, may not occur for a considerable space.

Walls of this kind consist of two faces of four-inch work, with very little to connect them together, and what is still worse the interior face often consists of bad brick, little better than rubbish. The practice of Flemish Bond has, notwithstanding, continued from the time of William and Mary, when it was introduced, with many other Dutch fashions, and our workmen are so infatuated with it, that there is now scarcely an instance of the old English Bond to be seen.

The frequent splitting of walls into two thicknesses has been attributed to the Flemish Bond alone, and various methods have been adopted for its prevention. Some have laid laths or slips of hoop-iron, occasionally, in the horizontal joints between the two courses; others have laid diagonal courses of bricks at certain heights from each other; but the effect of the last me-

* See *Masonry*, pages 306 and 307.

thod is questionable, as, in the diagonal course, by their not being continued to the outside, the bricks are much broken where the strength is required.

Other methods of uniting complete Bond with Flemish facings have been described, but they have been found equally unsuccessful. In *figures* 2 and 4, (*Plate* LXXXV,) the interior bricks are represented as disposed with intention to unite these two particulars; the Flemish facings being on one side of the wall only; but this, at least, falls short of the strength obtained by English Bond. Another evil attending this disposition of the bricks is, the difficulty of its execution, as the adjustment of the bricks in one course must depend on the course beneath, which must be seen or recollected by the workman; the first is difficult from the joints of the under-course being covered with mortar, to bed the bricks of the succeeding course; and, for the workman to carry in his mind the arrangement of the preceding course can hardly be expected from him; yet, unless it be attended to, the joints will be frequently brought to correspond, dividing the wall into several thicknesses, and rendering it subject to splitting, or separation. But, in the English Bond, the outside of the last course points out how the next is to be laid, so that the workman cannot mistake.

The outer appearance is all that can be urged in favour of Flemish Bond, and many are of opinion that, were the English mode executed with the same attention and neatness that is bestowed on the Flemish, it would be considered as equally handsome; and its adoption, in preference, has been strenuously recommended.

In forming English Bond, the following rules are to be observed:

1st, Each course is to be formed of headers and stretchers alternately.

2d, Every brick in the same course must be laid in the same direction: but, in no instance, is a brick to be placed with its whole length along the side of another; but to be so situated that the end of one may reach to the middle of the others which lie contiguous to it, excepting the outside of the stretching-course, where three-quarter bricks necessarily occur at the ends, to prevent a continued upright joint in the face-work.

3d, A wall, which crosses at a right-angle with another, will have all the bricks of the same level course in the same parallel direction, which completely bonds the angles, as shown by *figures* 1, 3, and 6.

The GREAT PRINCIPLE in the PRACTICE of BRICK-WORK lies in the proclivity or certain motion of absolute gravity, caused by a quantity or multiplicity of substance being added or fixed in resistible matter, and which, therefore, naturally tends downwards, according to the weight and power impressed. In bricklaying, this proclivity, chiefly by the yielding mixture of the matter of which mortar is composed, and cannot be exactly calculated, because the weight of a brick, or any other substance, laid in mortar, will naturally decline according to its substance or quality; particular care should, therefore, be taken, that the material be of one regular and equal quality all through the building; and, likewise, that the same force should be used to one brick as another; that is to say, the stroke of the trowel: a thing or point in practice of much more consequence than is generally imagined; for, if a brick be actuated by a blow, this will be a much greater pressure upon it than the weight of twenty bricks. It is, also, especially to be remarked, that the many bad effects arising from mortar not being of a proper quality should make masters very cautious in the preparation of it, as well as the certain quantity of materials of which it is composed, so that the whole structure may be of equal density, as nearly as can be effected.

Here we may notice a particular which often causes a bulging in large flank walls, especially when they are not properly set off on both sides; that is, the irregular method of laying bricks too high on the front edge: this, and building the walls too high on one side, without continuing the other, often causes the defects. Notwithstanding, of the two evils, this is the least; and bricks should incline rather to the middle of the wall, that one-half of the wall may act as a shore to the other. But even this method, carried too far, will be more injurious than beneficial, because the full width of the wall, in this case, does not take its absolute weight, and the gravity is removed from its first line of direction, which, in all walls, should be perpendicular and united; and it is farther to be considered that, as the walls will have a superincumbent

weight to bear, adequate to their full strength, a disjunctive digression is made from the right line of direction; the conjunctive strength becomes divided; and, instead of a whole or united support from the wall, its strength is separated in the middle, and takes two lateral bearings of gravity; each insufficient for the purpose; therefore, like a man overloaded either upon his head or shoulders, naturally bends and stoops to the force impressed; in which mutable state the grievances above noticed usually occur.

Another great defect is frequently seen in the fronts of houses, in some of the principal ornaments of Brick-work, as, arches over windows, &c., and which is too often caused by a want of experience in rubbing the bricks; which is the most difficult part of the branch, and ought to be very well considered: the faults alluded to, are the bulging or convexity in which the faces of arches are often found, after the houses are finished, and sometimes loose in the key or centre bond. The first of these defects, which appears to be caused by too much weight, is, in reality, no more than a fault in the practice of rubbing the bricks too much off on the insides; for it should be a standing maxim (if you expect them to appear straight under their proper weight) to make them the exact guage on the inside, that they bear upon the front edges; by which means their geometrical bearings are united, and all tend to one centre of gravity.

The latter observation, of camber arches not being skewed enough, is an egregious fault; because it takes greatly from the beauty of the arch, as well as its significancy. The proper method of skewing all camber arches should be one-third of their height. For instance, if an arch is nine inches high, it should skew three inches; one of twelve inches, four; one of fifteen inches, five; and so of all the numbers between those. Observe, in dividing the arch, that the quantity consists of an odd number: by so doing, you will have proper bond; and the key-bond in the middle of the arches; in which state it must always be, both for strength and beauty. Likewise observe, that arches are all drawn from one centre; the real point of camber arches is got from the above proportion. First, divide the height of the arch in three parts; one is the dimensions for the skewing; a line drawn from that through

the point at the bottom to the perpendicular of the middle arch, gives the centre: to which all the rest must be drawn.

*Of* FOUNDATIONS.—*Rules to be observed in laying Foundations.*

If a projected building is to have cellars, or under-ground kitchens, there will commonly be found a sufficient bottom, without any extra process, for a good solid foundation. When this is not the case, the remedies are to dig deeper, or to drive in large stones with the rammer, or by laying in thick pieces of oak, crossing the direction of the wall, and planks of the same timber, wider than the intended wall, and running in the same direction with it. The last are to be spiked firmly to the cross-pieces, to prevent their sliding, the ground having been previously well rammed under them.

The mode of ascertaining if the ground be solid is by the rammer; if, by striking the ground with this tool, it shake, it must be pierced with a borer, such as is used by well-diggers; and, having found how deep the firm ground is below the surface, you must proceed to remove the loose or soft part, taking care to leave it in the form of steps, if it be tapering, that the stones may have a solid bearing, and not be subject to slide, which would be likely to happen if the ground were dug in the form of an inclined plane.

If the ground prove variable, and be hard and soft at different places, the best way is to turn arches from one hard spot to another. Inverted arches have been used for this purpose with great success, by bringing up the piers, which carry the principal weight of the building, to the intended height and thickness, and then turning reversed arches from one pier to another, as shown in *figure* 18, *(Plate* LXXXV.*)* In this case, it is clear that the piers cannot sink without carrying the arches, and consequently the ground on which they lie, with them. This practice is excellent in such cases, and should, therefore, be general, wherever required.

Where the hard ground is to be found under apertures only, build your piers on these places, and turn arches from one to the other. In the construction of the arches, some attention must be paid to the breadth of the insisting pier, whether it will cover the arch or not; for, suppose the middle

of the piers to rest over the middle of the summit of the arches, then the narrower the piers, the more curvature the supporting arch ought to have at the apex. When arches of suspension are used, the intrados ought to be clear, so that the arch may have the full effect: but, as already noticed, it will also be requisite here that the ground on which the piers are erected be uniformly hard; for it is better that it should be uniform, though not so hard as might be wished, than to have it unequally so: because, in the first case, the piers would descend uniformly, and the building remain uninjured; but, in the second, a vertical fracture would take place, and endanger the whole structure.

WALLS, &c.—The foundation being properly prepared, the choice of materials is to be considered. In places much exposed to the weather, the hardest and best bricks must be used, and the softer reserved for in-door work, or for situations less exposed. In slaking lime, use as much water only as will reduce it to a powder, and only about a bushel of lime at a time, covering it over with sand, in order to prevent the gas, or virtue of the lime, from escaping. This is a better mode than slaking the whole at one time, there being less surface exposed to the air.

Before the mortar is used, it should be beaten three or four times over, so as to incorporate the lime and sand, and to reduce all knobs or knots of lime that may have passed the seive. This very much improves the smoothness of the lime, and, by driving air into its pores, will make the mortar stronger: as little water is to be used in this process as possible. Whenever mortar is suffered to stand any time before used, it should be beaten again, so as to give it tenacity, and prevent labour to the bricklayer. In dry hot summer-weather use your mortar soft; in winter, rather stiff.

If laying bricks in dry weather, and the work is required to be firm, wet your bricks by dipping them in water, or by causing water to be thrown over them before they are used, and your mortar should be prepared in the best way. Few workmen are sufficiently aware of the advantage of wetting bricks before they are used; but experience has shown that works in which this practice has been followed have been much stronger than others wherein

it has been neglected. It is particularly serviceable where work is carried up thin, and in putting in grates, furnaces, &c.

In the winter season, so soon as frosty and stormy weather set in, cover your wall with straw or boards; the first is best, if well secured; as it protects the top of the wall, in some measure, from frost, which is very prejudicial, particularly when it succeeds much rain; for the rain penetrates to the heart of the wall, and the frost, by converting the water into ice, expands it, and causes the mortar to assume a short and crumbly nature, and altogether destroys its tenacity.

In working up a wall, it is proper not to work more than four or five feet at a time; for, as all walls shrink immediately after building, the part which is first brought up will remain stationary; and, when the adjoining part is raised to the same height, a shrinking or settling will take place, and separate the former from the latter, causing a crack which will become more and more evident, as the work proceeds. In carrying up any particular part, each side should be sloped off, to receive the bond of the adjoining work on the right and left. Nothing but absolute necessity can justify carrying the work higher, in any particular part, than one scaffold; for, wherever it is so done, the workman should be answerable for all the evil that may arise from it.

The distinctions of *Bond* have already been shown, and we shall now detail them more particularly; again referring to *Plate* LXXXV, in which the arrangement of bricks, in depths of different thicknesses, so to form *English Bond,* is shown in *figures* 1, 3, 6, and 7.

*The bond of a wall of nine inches* is represented by *fig.* 1. In order to prevent two upright or vertical joints from running over each other, at the end of the first stretcher from the corner, place the return corner-stretcher, which is a header, in the face that the stretcher is in below, and occupies half its length; a quarter-brick is placed on its side, forming together $6\frac{3}{4}$ inches, and leave a lap of $2\frac{1}{4}$ inches for the next header, which lies with its middle upon the middle of the header below, and forms a continuation of the bond. The three-quarter brick, or brick-bat, is called a *closer*.

Another way of effecting this is, by laying a three-quarter bat at the corner of the stretching course; for, when the corner-header comes to be laid over it, a lap of $2\frac{1}{4}$ inches will be left at the end of the stretchers below for the next header; which, when laid, its middle will come over the joint below the stretcher, and in this manner form the bond.

*In a fourteen-inch or brick-and-half wall, (fig. 3,)* the stretching course upon one side, is so laid that the middle of the breadth of the bricks, upon the opposite side, falls alternately upon the middle of the stretchers and upon the joints between the stretchers.

*In a two-brick wall, (fig 6,)* every alternate header, in the heading course, is only half a brick thick on both sides, which breaks the joints in the core of the wall.

*In a two-brick and a half wall, (fig. 7,)* the bricks are laid as shown in *figure* 6.

*Flemish Bond,* for a nine-inch wall, is represented in *figure* 2, wherein two stretchers lie between two headers, the length of the headers and the breadth of the stretchers extending the whole thickness of the wall.

*In brick-and-half Flemish bond, (fig. 4,)* one side being laid as in *figure* 2, and the opposite side, with a half-header, opposite to the middle of the stretcher, and the middle of the stretcher opposite the middle of the end of the header.

*Figure* 5 exhibits another arrangement of Flemish Bond, wherein the bricks are disposed alike on both sides of the wall, the tail of the headers being placed contiguous to each other, so as to form square spaces in the core of the wall for half-bricks.

The *Face of an upright-wall,* English Bond, is represented by *figure* 19, and that of Flemish Bond, by *figure* 20.

Brick-nogging is a mode of constructing a wall with a row of posts or quarters, disposed at three feet apart, with brick-work filling up the intervals. In this mode the wall is, generally, either of the thickness or breadth of a brick, and the wood-work flush on both sides with the faces of the bricks. Thin pieces of timber, laid horizontally from post to post, are so disposed

as to form the brick-work, between every two posts or quarters, into several compartments in the height of the story; each piece being inserted between two courses of brick, with its edges flush with the faces of the wall.

*Figure* 13 is that of the head of an aperture, with a part of each jamb, the arch being straight. The manner of drawing the joints are as follow: (see *figure* 17.)

Describe an equilateral triangle upon the width, AB, of the aperture; and, from the vertex, C, or opposite angular point, describe a small circle, with a radius equal to the thickness of a brick. Draw the upper line, DE, forming the extrados, at a distance equal to the height of four bricks from the intrados. Draw the skew-backs, AB, DE, one upon each side; and draw a line parallel to one of the skew-backs touching the small circle, and cutting the extrados line in F, and draw the line CF. Find the point G, in the same manner, and draw GC, and so on to the middle, when the operation will be complete.

By *figure* 14, is represented the head of an aperture with a part of each jamb, the head being an arch formed by two concentric arcs, less than a semi-circle. This kind of arch is called a *Scheme or Segment Arch. Figure* 15 is a *semi-circular arch. Figure* 16 is a *semi-elliptic arch,* struck from the two centres, A and B, and having the longer axis in a horizontal position.

GROINS.—In *figure* 12 is represented the mode of constructing Groins rising from octagonal piers, and which are very convenient in cellars, where the removal of great weights are required. This is Mr. Tapper's improvement on the common four-sided groin. The improvement consists in raising the angle of the groin from an octagonal pier, instead of a square one, which gives more strength, and, from the corners being removed, renders it more commodious for turning any kind of goods around it: and it is farther to be observed that, in this construction, the angles of the groin are strengthened by carrying the band round the diagonals of equal breadth, and affording better bond to the bricks.

CONSTRUCTION OF BRICK GROINS.—The construction of groins and arches has already been shown in this work, under the head of *Carpentry,* pages

109 to 118. We shall, therefore, only add that the difficulty attending the execution of a brick groin lies in the peculiar mode of appropriating proper bond at the intersecting of the two circles, as they gradually rise to the crown to an exact point. In the meeting or intersecting of these angles, the inner-rib should be perfectly straight, and perpendicular to a diagonal line drawn upon the plan. But no definition, either by lines or description, can be given equal to what may be gained by a little practice. After the centres are set, let the bricklayer apply two or three bricks to an angle, by which he will effectually see how to cut them, as well as the requisites of bond.

The workman must observe, that the manner of turning groins with respect to the sides, is the same as in other arches and centres, except in the angles, which must be traced by applying the bricks. If the arch is to be rubbed and guaged, you must divide each arch into an exact number of parts, and extend the lines till they meet in the groin; by which means you will easily find the curve for the angle, from which you must make your templets; observe, in fixing the centres, that the carpenters raise them something higher at the crown, to allow for settling, which frequently happens, sometimes by the pressure upon the butments, otherwise from the length of the crown.

Be cautious, in building of vaults, that the piers or butments are of sufficient strength: all butments to vaults, whether groined, or only arched, should be one-sixth part of the width of the span; and moreover, if there is any great weight to be sustained, bridgings of timber should be framed, to discharge the weight from the crown of the arch; after a vault or groin is finished, it is highly necessary to pour on a mixture of terras, or lime and water, on the crown; and give it some little time to dry, before you strike the centres, in order to cement the whole together.

CORNICES.—Ornamental brick cornices are represented in *figures* 21 and 22. The first shows the rudiments of the Doric entablature, and the second is a *Dentil Cornice.* Many pleasing dispositions of bricks may thus be made, frequently without cutting, or by chamfering only.

## OF A NICHE IN BRICK-WORK.

The formation of niches has already been described under *Carpentry*, pages 134 to 138. The practice of this in Brick-work is the most difficult part of the profession, on account of the very thin size the bricks are obliged to be reduced down to at the inner circle, as they cannot extend beyond the thickness of one brick at the crown or top; it being the usual, as well as much the neatest, method, to make all the courses standing.

The most familiar way to reduce this point to practice, is to draw the front, back, &c., and make a templet of pasteboard, after you have divided the arch for the number of bricks. Observe that, one templet for the standing courses will answer for the front, and one for the side of the brick; and at the top of the straight part, whence the niche takes its spring, remember to make a circle of the diameter of eight or nine inches, and cut this out of pasteboard also, and divide it into the same number of parts as the outward circle; from which you will get the width of your front-templet at the bottom. The reason of this inner circle is to cut off the thin conjunction of points that must all finish in the centre, and which in bricks could never be worked to that nicety; it being impossible to cut bricks correctly nearer than to half an inch thick; within the inner circle the bricks must be lying. It will be necessary to have one templet made convex, to try the faces of bricks to, as well as sitting of them, when they are gauged. The stone you rub the faces of the bricks upon, must be cut at one end in the exact form of the niche, or it will be impossible to face them properly. The level of the flat sides of the bricks is got by dividing the back into the number of parts with the front, and all struck to the centre; from the circle of the front of one brick, set your level, which will answer for the sides of the whole: take care that the bricks hold their full guage at the back; or, when you come to set them, you will have much trouble. Works of this kind, as they require much skill and attention, should bear a handsome price.

## CONSTRUCTION OF OVENS.

The oven, on the old principle, for the use of bakers, was usually of an oval shape; the sides and bottom of brick, tiles, and lime, and arched over at top, with a door in front; and at the upper part, an inclosed closet, with an iron grating, for the tins to stand on, called the *Proving Oven.* To heat such ovens, faggots are introduced and burnt to ashes, which are then removed, and the bottom cleaned out. This operation requires some time, during which much of the heat escapes. A still further length of time is required for putting in the bread, and unless much more fuel is expended than is really necessary, in heating an oven upon this principle, it gets chilled before the loaves are all set in, and they are, consequently, injured.

To remedy this inconvenience, many ovens have latterly been built upon a solid base of brick and lime, with a door of iron, furnished with a damper to carry off the steam as it rises, and heated with fossil coal. On one side is a fire-place or furnace, with grating, ash-hole, and iron door, similar to that under a copper, with a partition to separate it from the oven, and open at one end. Over this is a middling-sized copper, or boiler, with a cock at the bottom, and on one side of it is placed the proving oven; the whole being faced with brick and plaster.

When this oven is required to be heated, the boiler is filled with water, and the fire being kindled, the flame spreads around the oven, in a circular direction, and renders it as hot as if heated with wood, without causing dirt or ill smell, while the smoke escapes through an aperture, which may pass into the kitchen chimney. When the coal is burnt to a cinder, there is no necessity for removing it, as it prevents the oven from cooling while the bread is setting in, and keeps up a regular heat till the door is closed. The advantages of an oven built upon this principle, are too obvious to require comment.

# BRICKLAYING.

*Design for Coal Oven upon the new approved principle*

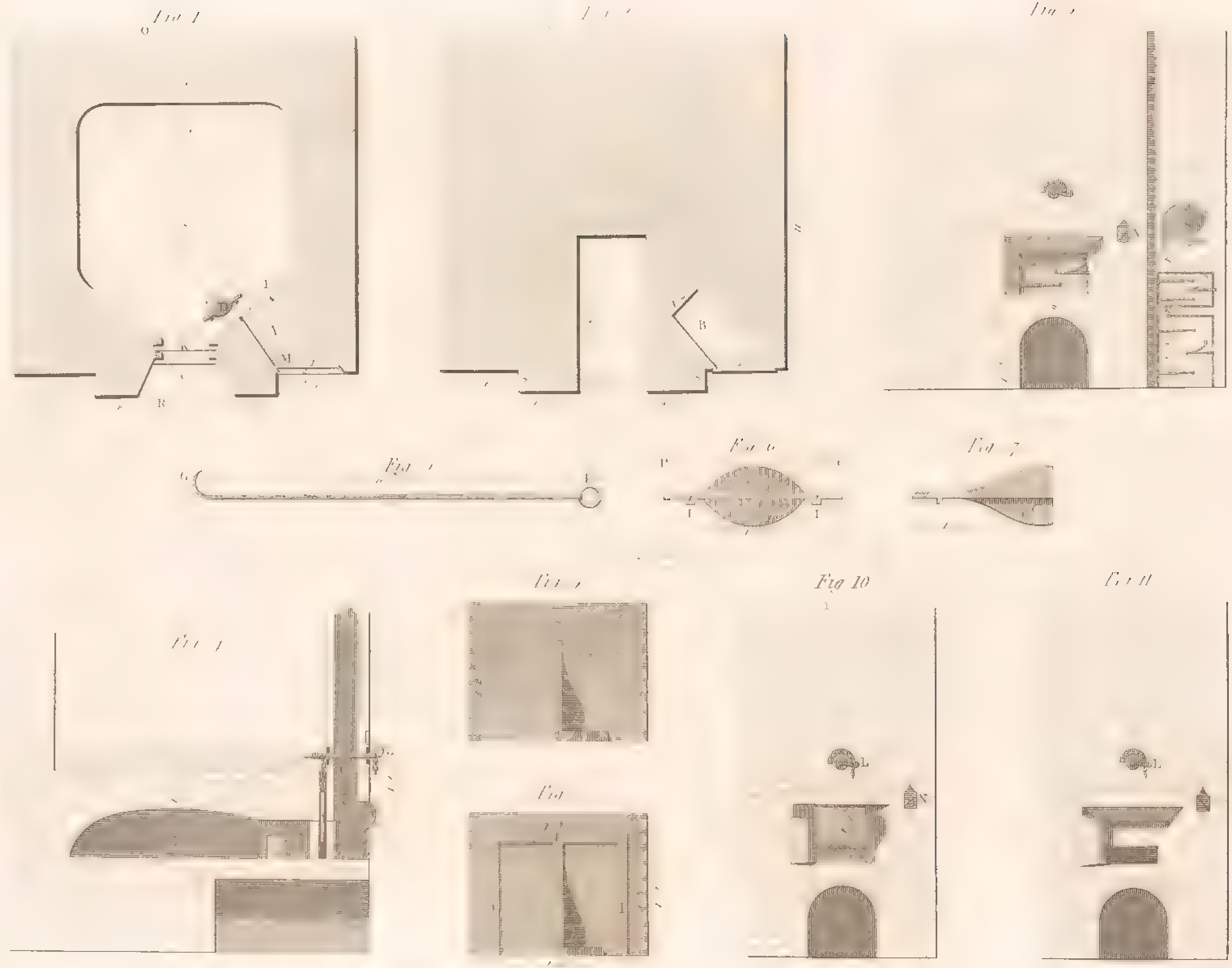


*Plate* LXXXVI exhibits, in detail, the improved plan of an oven, on the new construction. It has been communicated by Mr. Elsam, the Architect, under whose directions it has been constructed in various public buildings in different parts of the United Kingdom.

*Figure* 1 is the plan of the oven. The fire is put into the furnace, A, upon wrought iron bars, which are fixed an inch and a half below the level of the oven, to prevent the cinders from entering it. The outside of the furnace is inclosed with two cast-iron doors, (1, 2, in plan.) The ashes fall into the ash-pit beneath, B, *(fig.* 2,*)* the door of which is marked 3, in the elevation, *(fig.* 3.*)*

While the coals are burning, the mouth of the oven is inclosed only by the curved cast-iron door, or blower, B, shown in the section of the oven, *(fig.* 4,*)* and elevation, *(fig.* 10,*)* and which is so shaped in order to make a proper passage for the smoke to the flue, C. This door, or blower, is not hung, but is put up and taken away by hand.

When the oven is sufficiently hot, a man, placed at the mouth of the oven, with the iron bar, E, (*fig.* 5,) slides the cast-iron stopper, D, (*fig.* 1 and 6,) to the angle, F, where it stops, as shown by the dotted lines; then going to the mouth of the furnace, he hooks the crooked part, G, of the same iron bar, *(fig.* 5.*)* into the circular hole of the stopper, H, *(fig.* 7,*)* and pulls the fillet, IIIII, *(fig.* 8,*)* into the frame of the furnace, whereto it fits. This stopper is made to slide, but not in a groove, as the cinders might sometimes prevent its being shut.

*Figure* 8 represents an iron frame, to be fixed round the mouth of the furnace in the inside. The opening of the mouth to be one foot two inches wide, and one foot high, which receives the fillets of the stopper, III.

The door, K, (*fig.* 4,) is fastened to an iron chain, and is raised or let down, at pleasure, by turning the lever, L, *(figures* 4, 10.*)* This door is used to diminish, as much as possible, the mouth of the oven, while the bread is putting in, and to prevent the heat from escaping. To the handle of the lever is hung an iron pin, with a chain, and over it is a semi-circular iron plate, fastened to the wall, with five holes drilled in it to receive the pin, which will regulate the height of the door, K, at pleasure.

When bread is baking, the curved door, B, not being then wanted, is taken away; and the two doors of the oven, with the two doors of the furnace, are shut up.

At the top of the furnace, M, *(fig. 4,)* is a small flue, about three inches square, which communicates with the flue of the oven. The use of this small flue is to leave a passage for the sulphur that may remain in the ashes, and might injure the bread while baking. The communication of this small flue of the oven is opened or shut by mean of an iron slider, N, *(fig. 10.)* Over the furnace is a niche, *(fig. 3,)* with a boiler of hot water.

It has been noticed that, in ovens on this construction, whatever be the size of the fire-place, it is always proper to set the bars eight or ten inches in from the door, which will keep a supply of coals warming before they are pushed forward into the fire. The importance of this is known to those who have attended to the effect of every fresh supply of coals to the boilers of steam-engines, as it instantly stops the boiling, unless this precaution is attended to. It also prevents, in a great measure, the cold air getting in between the door and frame of the fire-place, which frequently happens, from the difficulty of fitting iron doors to iron frames.

Ovens, on the improved construction, will hold, according to their size, as follows:

Eight feet wide, and seven feet deep, eight bushels of bread.

Nine feet wide, and seven and a half feet deep, ten bushels.

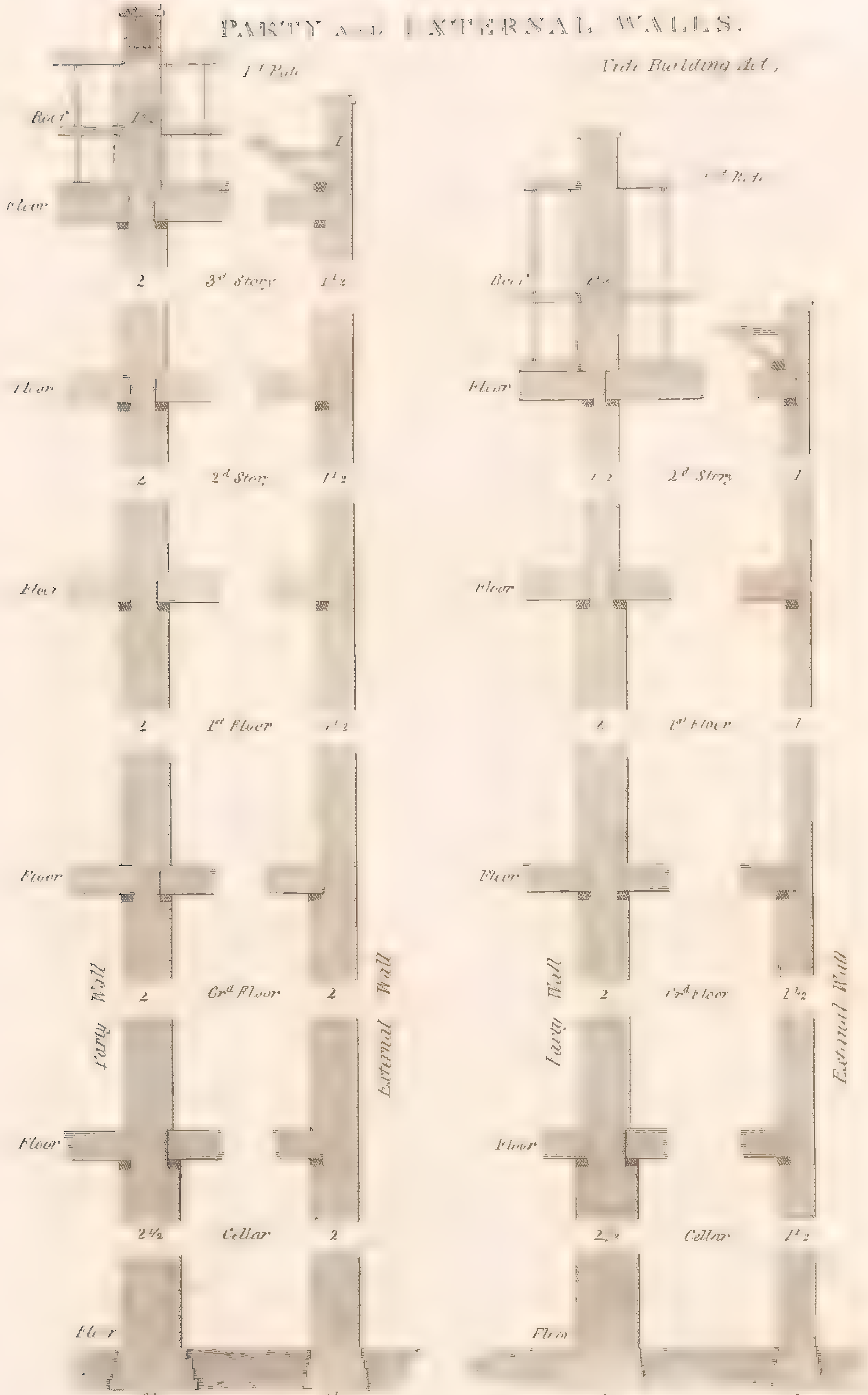
Ten feet wide, and eight and a half feet deep, twelve bushels.

If required to hold less than eight bushels, or more than twelve, the proportions, of course, must vary accordingly.

The oven represented in the plate is eight feet wide and seven deep; and, therefore, as stated above, it is adapted for eight bushels of bread. The fire-hole, or furnace, *(fig. 1,)* enters the oven in a direction, diagonal with the farthest corner; the sides of the oven are carried nearly straight, and turned as sharp as possible at the haunch and shoulder, this form being supposed better calculated to retain the heat than any other: the flue is immediately over the entrance, as shown in *figures* 1 and 4. Welsh lumps, or fire-bricks,

# PARTY AND EXTERNAL WALLS.

*Vide Building Act,*




*Drawn by R. Elsam Archt*

are used for the furnace. In a work of this nature, it is usual to introduce a considerable quantity of old iron hoops, more especially around and over the oven, in order to keep the work together. This precaution is adviseable on all occasions where great heat is required.

In building the oven, the crown is turned with the bricks on end, as shown in the section, (*fig.* 4); and, instead of centering, the custom is to fill the whole space with sand, clay, or rubbish, which is well trodden down, and fashioned to the shape which it is intended the crown shall be of. When the upper work is finished, the sand is dug out or removed by the mouth of the oven.

Other particulars, interesting to the bricklayer, will be found in the Explanation of Terms, used by Bricklayers and Plasterers, hereafter.

## SUBSTANCE OF THE BUILDING ACT, &c.

By the Building-Act, of the 14th of Geo. III., every master-builder, or owner, in the cities of London and Westminster, the Weekly Bills of Mortality, the Parishes of Saint Mary-la-Bonne, Paddington, St. Pancras, and St. Luke's, Chelsea, prior to beginning any building, within the first and seventh rates, must give twenty-four hours notice of his intention to the district-surveyor, descriptive of the edifice to be erected or altered. And the proprietors of houses and grounds must also give three months' notice to pull down old party-walls, party-arches, party fence-walls, or quarter partitions, when decayed, or of insufficient thickness, and to be left with the owner or occupier of such house; and, if empty, such notice to be stuck up on the front door, or front of such house.

The same Act also recites, that every front side or end wall, not being a *party-wall*, shall be deemed an *external wall*.

The thicknesses of party and external walls are described only of the *first, second, third,* and *fourth,* rates of building, the thicknesses of which, together with the prescribed thicknesses of the walls to the backs of the chimnies, in the several party and external walls, are described in *Plates* LXXXVII,

LXXXVIII, and LXXXIX, which will fully elucidate the subject, as regards the construction of party and external walls, with the chimnies therein.

The footings of external walls must have equal projections, except where the adjoining buildings will not admit of it, in which case the builder must be guided by circumstances, and conform, as nearly as possible, to the directions of the Act, under the guidance of the district surveyor.

Walls, and other external inclosures to buildings, of the first, second, third, fourth, and fifth, rates, must be of brick, stone, artificial stone, lead, copper, tin, slate, tile, or iron, or a combination of those articles; but for foundations, wood-planks may be used.

If it should be required to make recesses in external walls, they must be arched, in order that the arches and recesses may each be equal in thickness to one brick: of course recesses cannot be formed in walls which are only one brick thick.

External walls of buildings, of the first, second, third, and fourth, rates, cannot be converted into party-walls, unless they are of the heights and thicknesses above the footings required for party-walls.

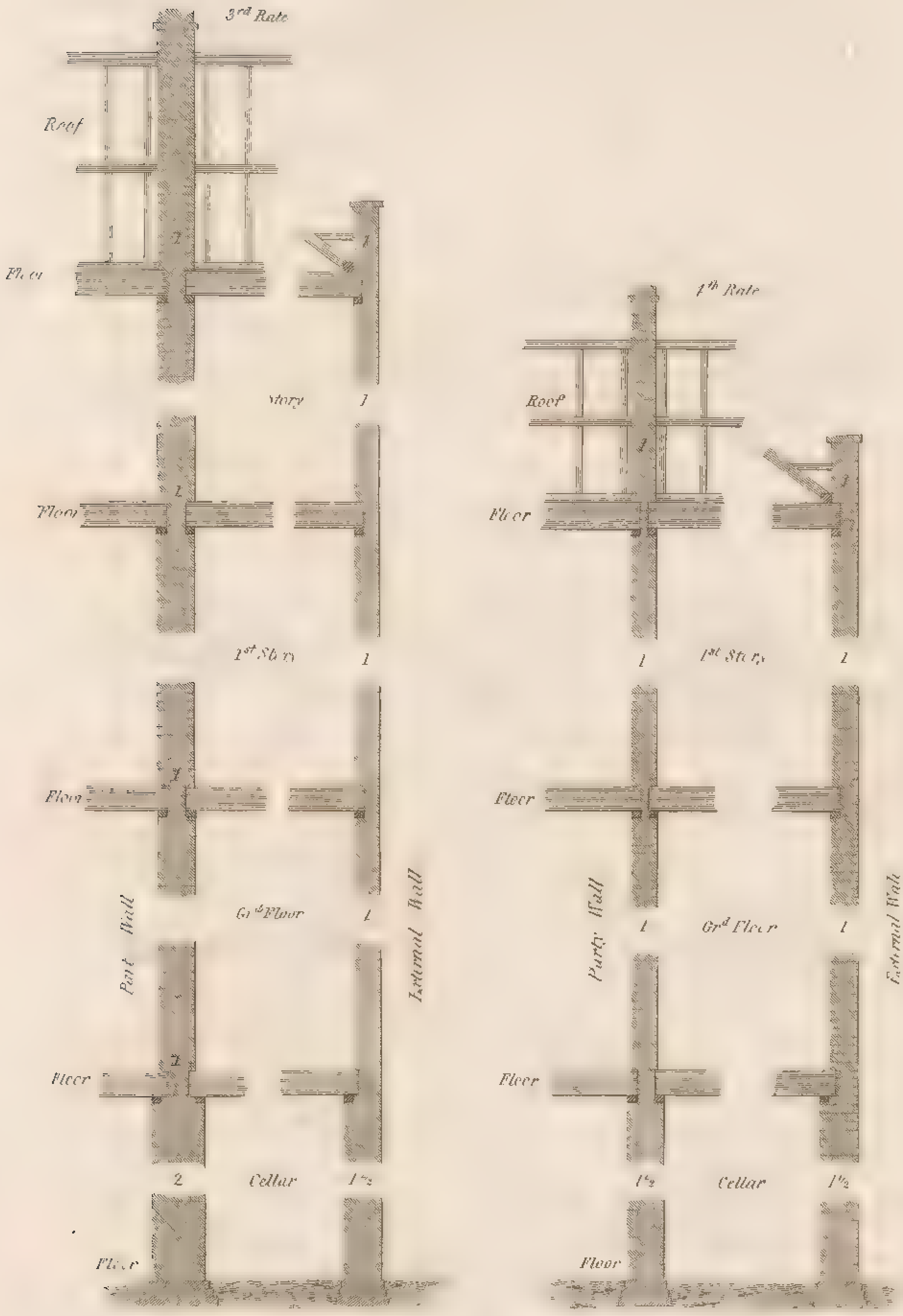
Party-walls appertain to such persons who are the owners of first, second, third, or fourth, rate buildings, and who do not intend to have distinct and separate walls on such sides as are contiguous to other buildings. Party-walls must be placed half and half on the ground of each of the owners, without any notice being given, provided it adjoins vacant ground.

Party-walls, or additions thereto, must be carried up at least eighteen inches above the roofs of the adjoining premises, measuring at right angles with the back rafters, and twelve inches above the gutters of the highest buildings against which they may abut, unless the height of the party-walls shall exceed those of the parapets, or blocking courses; in which events, they may be left less than twelve inches above the gutters, at distances of two feet six inches from the fronts of the parapets and blocking courses.

Where it occurs that dormer-windows, or the heads of trap-doors, &c. are fixed upon flats, or roofs, within four feet of party-walls, such party-walls must be carried two feet higher than such dormer or erections previously constructed.

# PARTY AND EXTERNAL WALLS.

(Vide Building Act.)

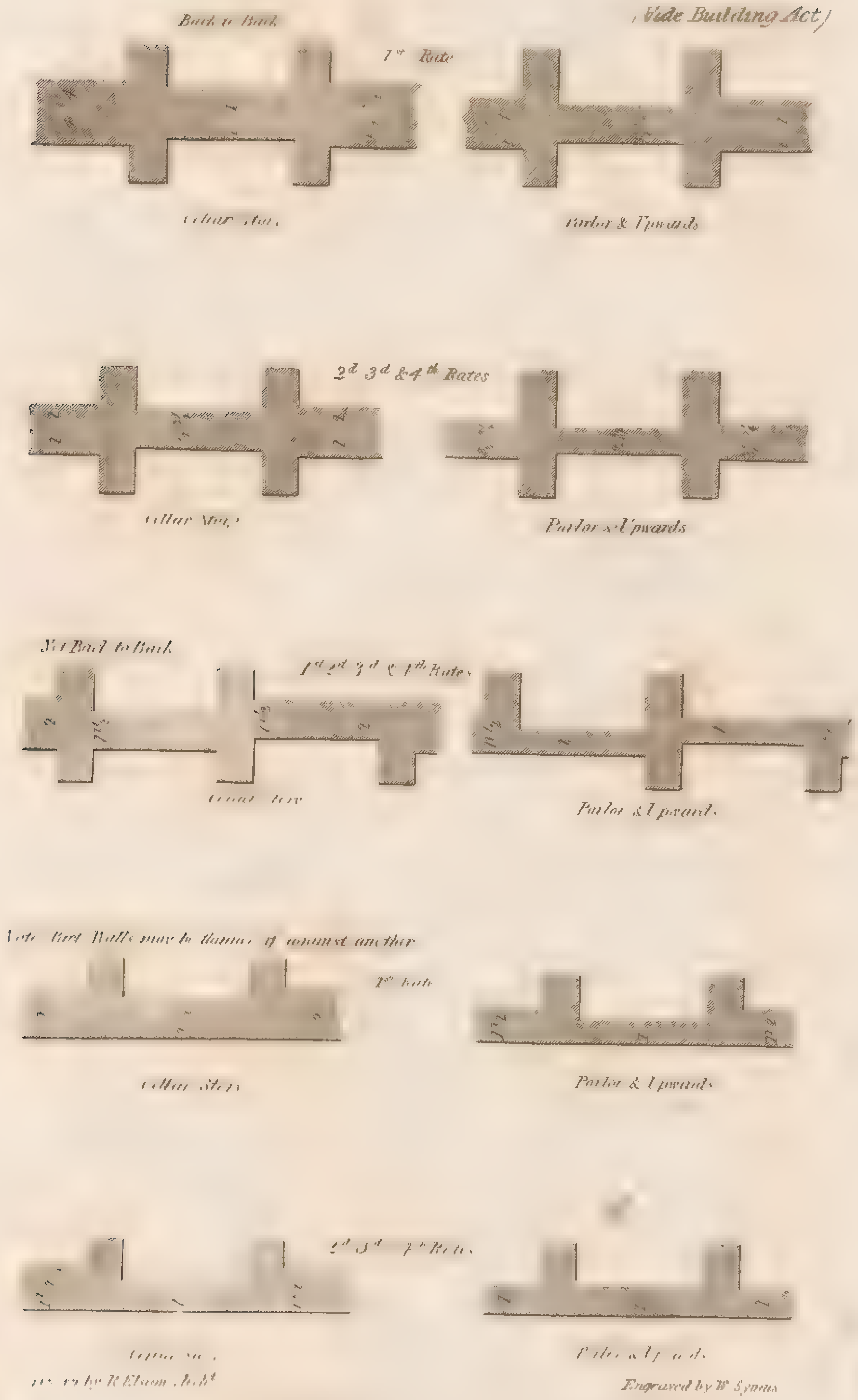



Drawn by R. Elsam Arch.t

Engraved by W. Symns

London Published by T. Kelly 17, Paternoster Row Oct.r 9 1824

# BACKS OF CHIMNIES IN PARTY WALLS.

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Recesses must not be made in party-walls, that will reduce any parts thereof to thicknesses less than the Act requires for the highest rates of buildings, to which such walls shall appertain, except for chimney-flues, girders, &c., or for embracing the ends of piers or walls.

Openings must not be made in party-walls, unless to communicate between two or more stacks of warehouses, or between one approved stable-building and another, in which cases, the communications must have iron-doors, not less than a quarter of an inch thick in the panels, fixed in stone frames and sills.

Openings, also, may be made for public passage-ways on the ground-floor for foot passengers, or sufficiently wide for the egress and regress of carriages of every description; as likewise for cattle, provided such passages or carriage-ways are arched over with brick or stone, or brick and stone united, of the thickness of one brick and a half at the least, for first-rate and second-rate buildings, and not less than one brick for the third and fourth rates; and where cellars, or vaults, are required under such passages, or archways, they must be arched over throughout in the same manner, and according to the same proportions before-mentioned. Party-walls, party-arches, or chimney-shafts, old or new, may be cut into, except in the following instances. Where the fronts of buildings are in lines with each other, incisions may be cut, either in the rear or principal fronts, for the purposes of inserting the ends of any new external walls of any intended adjoining building, but such incisions must not be made more than nine inches deep from the outward faces of the external walls, nor beyond the centres of the party-walls. And for the more convenient insertion of bressumers and story-posts, to be fixed on the ground-floors, either in the back or principal front walls, recesses may be cut from the foundations of the new walls to the heights of the bressumers, fourteen inches deep from the outward faces of such walls, and four inches wide in the cellar stories, and two inches wide in the ground stories.

Party-walls may also be cut into for the purposes of tailing-in stone steps or stone landings, or for bearers to wood-stairs, or for laying in stone corbels, for supporting chimney-jambs, girders, purlines, binding or trimming joists, or any other principal timbers.

Perpendicular recesses may also be cut in party-walls, which are not less than one brick and a half thick, for the purposes of inserting walls or piers; but the incisions must not be more than fifteen inches deep; and where two or more incisions are made in the same description of walls, they must not approximate nearer to each other than ten feet.

Incisions may be made in party-walls for any of the preceding purposes, that is, provided they are not likely to injure, remove, or endanger the timbers, chimnies, flues, or internal finishings, of the adjoining buildings. The incisions, indents, cuts, or recesses, before-mentioned, must be made good as soon as possible; and during the time such operations are carrying into effect, the buildings adverted to must be carefully pinned up, where required, with bricks, stone, slate, tile, or iron-bedded, in mortar.

The portions of houses, or other buildings, which are contrived to be built over public passages, or gateways, being divided, and again sub-divided, into rooms and stories, the property of different owners, when built or re-built, must have party-walls and party-arches, at least a brick and a half thick, for first and second-rate buildings, and one brick thick for second and third-rate buildings, between the several rooms or stories belonging to the different proprietors; but the buildings to the Inns of Court are exempt from the latter regulation, it being deemed sufficient to build party-walls where any rooms or chambers communicate with the stair-cases, the walls in which instances are subject to the same regulations as other party-walls.

Where the lower-rate buildings adjoin those of higher rates, the additions intended to be made thereto must be built according to the rules prescribed for the higher rates.

Party-walls, which are built against other buildings, must be of the same thicknesses with the walls of the highest adjoining buildings in the stories next below the roofs; but such party-walls must not be erected, unless they can be done with the greatest safety to the adjoining walls or buildings.

Dwelling-houses, or other buildings, four stories high from the foundations, exclusive of the rooms in the roofs, must have party-walls, according to the third-rate of buildings, although such houses, or other buildings, estimated by the numbers of squares on the ground-floor, are of the fourth-

rate. And every dwelling-house, or other building, exceeding four stories in height from the foundations, exclusive of rooms in the roofs, must have party-walls according to the first-rate, although such houses, or other buildings, are not of the first-rate, that is, according to the number of squares on the ground-floor.

Chimnies must not be erected on timbers, unless it be indispensably necessary to pile and plank the foundations.

Chimnies may be built in party-walls back to back; but they must not be less in thicknesses, from the centres of such walls, than are described in the plate of plans elucidating the intention of the Act of Parliament, as regards the construction of chimnies in party and external walls.

The breasts of chimnies in party-walls must not, in any instance, be less than one brick thick in the cellar, and half a brick in every other story, and the divisions or widths, between the flues, must never be less than half a brick thick. The flues in party-walls may be built against each other, but must not approach nearer than two inches to the centres of such walls.

The breasts of chimnies and backs, together with the flues, must, in all cases, be rendered or pargetted, care being taken that timbers are not any where introduced for supporting the breasts, which must be carried by strong brick or stone arches, assisted by wrought-iron bars, as many as are requisite to each opening.

The flues in party-walls against vacant ground, must be lime-whited, or marked in some durable manner, and immediately after any other houses are erected against them, whatever is deemed requisite to be done to the flues must, as soon as possible, be completed.

Brick-flues, or funnels, must not be made on the outside of any building, of the first, second, third, or fourth, rates, next to any street, square, road, or passage, so as to project beyond the general line of the buildings; nor must any funnel, or pipe of iron, copper, or tin, for the conveyance of smoke or steam, be fixed near any public street, or court, &c., to buildings of the first, second, third, or fourth, rate description; nor must any pipes, for the conducting of smoke, be fixed within any of the before-mentioned buildings, nearer than fourteen inches to any timber, or other materials subject to take fire.

Every dwelling-house, which exceeds NINE squares of building on the ground-floor, including internal and external walls, are deemed the first-rate or class of buildings, and subject to be built in manner before-described; and, likewise, according to the thicknesses of the walls, drawn and figured in the sections and plans hereunto referred.

Dwelling-houses, also, which exceed FIVE squares of building, and are not more than NINE, are deemed second-rate houses.

Dwelling-houses, also, which exceed THREE squares and ONE-HALF, and are not more than FIVE squares, are deemed third-rate houses.

Dwelling-houses, also, which shall not exceed THREE and ONE-HALF squares, are deemed fourth-rates.

Fifth, sixth, and seventh, rate buildings, may be built of any dimensions, provided the conditions, stipulated in the Act of Parliament, are adhered to.

DISTRICT-SURVEYORS' FEES.

| | £. | s. | d. |
|---|---|---|---|
| For every first-rate building | 3 | 10 | 0 |
| For every alteration or addition | 1 | 15 | 0 |
| For every second-rate | 3 | 3 | 0 |
| For every alteration or addition | 1 | 10 | 0 |
| For every third-rate | 2 | 10 | 0 |
| For every alteration or addition | 1 | 5 | 0 |
| For every fourth-rate | 2 | 2 | 0 |
| For every alteration or addition | 1 | 1 | 0 |
| For every fifth-rate | 1 | 10 | 0 |
| For every alteration or addition | 0 | 15 | 0 |
| For every sixth-rate | 1 | 1 | 0 |
| For every alteration or addition | 0 | 10 | 6 |
| For every seventh-rate | 0 | 10 | 6 |
| For every alteration or addition | 0 | 5 | 0 |

*The District-Surveyors are elected by the Magistrates for the Counties of Middlesex and Surrey.*

# CHAPTER IX.

## PLASTERING.

In modern practice, Plastering, by its recent improvements, occurs in every department of architecture, both internally and externally. It is more particularly applied to the sides of the walls, and the ceilings of the interior parts of buildings, and, also, for stuccoing the external parts of many edifices.

In treating on this subject, we shall divide Plastering under its several heads: as *plastering on laths*, in its several ways; *rendering* on brick and stone; and, finally, the finishing to all the several kinds of work of this description; as well as modelling, and casting the several mouldings, both ornamental and plain; stuccoing, and other outside compositions, which are applied upon the exterior of buildings; and, the making and polishing the *scagliola,* now so much used for columns, and their antæ, or pilasters, &c.

Lime forms an essential ingredient in all the operations of this trade. This useful article is vended at the wharfs about London in bags, and varies in its price from thirteen shillings to fifteen shillings per hundred pecks. Most of the lime made use of in London is prepared from chalk, and the greater portion comes from Purfleet, in Kent; but, for stuccoing, and other work, in which strength and durability is required, the lime made at Dorking, in Surrey, is preferred.

The composition, known as Plaster of Paris, is one on which the Plasterer very much depends for giving the precise form and finish to all the better parts of his work; with it he makes all his ornaments and cornices, besides mixing it in his lime to fill up the finishing coat to the walls and ceilings of rooms.

The stone, from which the plaster is obtained, is known to professional men by several names, as *sulphate of lime, selenite, gypsum,* &c.; but its common name seems to have been derived from the immense quantities which have been taken from the hill named *Mont-Martre,* in the environs of Paris. The stone from this place is, in its appearance, similar to common free-stone, excepting its being replete with small specular crystals. The French break it into fragments of about the size of an egg, and then burn it in kilns, with billets of wood, till the crystals lose their brilliancy; it is then ground with stones, to different degrees of fineness, according to its intended uses. This kind of specular gypsum is said to be employed in Russia, where it abounds, as a substitute for glass in windows.

According to the chymists, the specific gravity of gypsum, or Plaster of Paris, is from 1.872 to 2.311, requiring 500 parts of cold and 450 of heat, to dissolve it; when calcined, it decrepitates, becomes very friable and white, and heats a little with water. In the process of burning, or calcination, it loses its water of crystallization, which, according to Fourcroy, is 22 per cent.

The plaster commonly made use of in London is prepared from a sulphate of lime, produced in Derbyshire, and called alabaster. Eight hundred tons are said to be annually raised there. It is brought to London in a crude state, and afterwards calcined, and ground in a mill for use, and vended in brown-paper bags, each containing about half a peck; the coarser sort is about fourteen-pence per bag, and the finest from eighteen to twenty-pence. The figure-makers use it for their casts of anatomical and other figures; and it is of the greatest importance not only to the plasterer, but to the sculptor, mason, &c.

The working-tools of the plasterer consist of a *spade,* of the common sort, with a *two or three-pronged rake,* which he uses for the purpose of mixing his mortar and hair together. His *trowels* are of two sorts, one kind being of three or four sizes. The first sort is called the *laying* and *smoothing-tool;* its figure consists in a flat piece of hardened iron, very thin, of about ten inches in length, and two inches and a half in width, ground to a semi-circular shape at one end, while the other is left square; on the back of the plate, and

nearest to the square end, is riveted a piece of small rod-iron, with two legs, one of which is fixed to the plate, and the other, adapted for being fastened in a round wooden handle. With this tool all the first coats of plastering are put on; and it is also used in setting the finishing coat.

The trowels of the plasterer are made more neatly than the tools of the same name used by other artificers. The largest size is about seven inches long on the plate, and is of polished steel, two inches and three-quarters at the heel, diverging to an apex or point. To the wide end is adapted a handle, commonly of mahogany, with a deep brass ferrule. With this trowel the plasterer works all his fine-stuff, and forms cornices, mouldings, &c. The other trowels are made and fitted-up in a similar manner, varying gradually in their sizes from two to three inches in length.

The plasterer likewise employs several small tools, called *stopping* and *picking-out tools;* these are made of steel, well polished, and are of different sizes, commonly about seven or eight inches long, and half an inch wide, flattened at both ends, and ground away till they are somewhat rounding. With these he models and finishes all the mitres and returns to the cornices, and fills up and perfects the ornaments at their joinings.

The workman in this art should keep all his tools very clean; they should be daily polished, and never put away without being wiped and freed from plaster.

In the practice of plastering many rules and models of wood are required. The rules, or *straight-edges* as they are called, enable the plasterer to get his work to an upright line; and the models guide him in running plain mouldings, cornices, &c.

The Cements made use of, for the interior work, are of two or three sorts. The first is called *lime* and *hair*, or coarse stuff; this is prepared in a similar way to common mortar, with the addition of hair, from the tan-yards, mixed in it. The mortar used for lime and hair is previously mixed with the sand, and the hair added afterward. The latter is incorporated by the labourers with a three-pronged rake.

FINE-STUFF, is pure lime, slaked with a small portion of water, and afterwards well saturated, and put into tubs in a semi-fluid state, where it is allowed to settle, and the water to evaporate. A small proportion of hair is sometimes added to the fine-stuff.

STUCCO, for inside walls, called *trowelled* or *bastard stucco,* is composed of the fine-stuff above described, and very fine washed sand, in the proportion of one of the latter to three of the former. All walls, intended to be painted, are finished with this stucco.

MORTAR, called *gauge-stuff,* consists of about three-fifths of fine-stuff and one of Plaster of Paris, mixed together with water, in small quantities at a time: this renders it more susceptible of fixing or setting. This cement is used for forming all the cornices and mouldings, which are made with wooden moulds. When great expedition is required, the plasterers guage all their mortar with Plaster of Paris. This enables them to hasten the work, as the mortar will then set as soon as laid on.

PLASTERERS have technical words and phrases, by which they designate the quality of their work, and estimate its value.

By LATHING is meant the nailing up laths, or slips of wood, on the ceiling and partitions. The laths are made of fir or oak, and called *three-foots* and *four-foots,* being of these several lengths: they are purchased by the bundle or load.

There are three sorts of laths; viz. *single laths, lath and half,* and *double laths.* Single laths are the cheapest and thinnest; lath and half denotes one third thicker than the single lath; and double laths twice their thickness. The laths generally used in London are made of fir, imported from Norway, the Baltic, and America, in pieces called *staves.* Most of the London timber-merchants are dealers in laths; and there are many persons who confine themselves exclusively to this branch of trade.

The fir-laths are generally fastened by cast-iron nails, whereas the oaken ones require wrought-iron nails, as no nail of the former kind would be found equal to the perforation of the oak, which would shiver it in pieces by the act of driving.

In lathing ceilings, it is adviseable that the plasterer should make use of laths of both the usual lengths, and so manage the nailing of them, that the joints should be as much broken as possible. This will tend to strengthen the plastering laid thereon, by giving it a stronger key or tie. The strongest laths are adapted for ceilings, and the slightest or single laths for the partitions of buildings.

Laying consists in spreading a single coat of lime and hair all over a ceiling or partition; taking care that it is very even in every part, and quite smooth throughout: this is the cheapest manner of plastering.

Pricking-up is similar to *laying*, but is used as a preliminary to a more perfect kind of work. After the plastering has been put up in this manner, it is *scratched* all over with the end of a lath, in order to give a key or tie to the *finishing coats,* which are to follow.

Lathing, laying, and set, are applied to work that is to be lathed as already described, and covered with one coat of lime and hair; and, when sufficiently dry, finished by being covered over with a thin and smooth coat of lime only, called by the plasterer *putty,* or *set.* This coat is spread with the smoothing trowel, and the surface finished with a large flat hog's-hair brush. The trowel is held in the right hand, and the brush in the left. As the plasterer lays on the set, he draws the brush backwards and forwards over it, till the surface is smooth.

Lathing, floating, and set, consists of lathing and covering with a coat of plaster, which is pricked up for the floated work, and is thus performed: The plasterer provides himself with a strong rule, or straight-edge, often from ten to twelve feet in length; two workmen are necessarily employed therein. It is began by plumbing with a plumb-rule, and trying if the parts to be floated are upright and straight, to ascertain where filling up is wanting. This they perform by putting on a trowel or two of lime and hair only: when they have ascertained these preliminaries, the *screeds* are prepared.

A Screed, in plastering, is a stile formed of lime and hair, about seven or eight inches wide, guaged exactly true. In floated-work these screeds are made, at every three or four feet distance, vertically round a room, and

are prepared perfectly straight by applying the straight-edge to them to make them so; and, when all the screeds are formed, the parts between them are filled up flush with lime and hair, or *stuff*, and made even with the face of the screeds. The straight-edge is then worked horizontally upon the screeds, to take off all superfluous *stuff*. The floating is thus finished by adding *stuff* continually, and applying the rule upon the screeds till it becomes, in every part, quite even with them.

Ceilings are floated in the same manner, by having screeds formed across them, and filling up the intermediate spaces with *stuff*, and applying the rule as for the walls.

Plastering is good or bad, in proportion to the care taken in this part of the work; hence the most careful workmen are generally employed therein.

The SET to the floated work is performed in a similar way to that already described for the laid plastering; but floated plastering, for the best rooms, is performed with more care than is required in an inferior style of work. The setting, for the floated work, is frequently prepared by adding to it about one-sixth of Plaster of Paris, that it may fix more quickly, and have a closer and more compact appearance. This, also, renders it more firm, and better adapted for being whitened, or coloured, when dry. The drier the pricking-up coat of plastering is, the better for the floated stucco-work; but if the floating is too dry before the last coat is put on, there is a probability of its peeling off, or cracking, and thus giving the ceiling an unsightly appearance. These cracks, and other disagreeable appearances in ceilings, may likewise arise from the weakness of the laths, or from too much plastering, or from strong laths and too little plastering. Good floated work, executed by a judicious hand, is very unlikely to crack, and particularly if the lathing be properly attended to.

RENDERING and SET, or RENDERING, FLOATED, and SET, includes a portion of the process employed in both the previous modes, with the exception that no lathing is required in this branch of the work. By *rendering* is meant that one coat of lime and hair is to be plastered on a wall of brick or stone; and the *set* implies that it is again to be covered and finished with fine stuff, or

putty. The method of performing this is similar to that already described for the setting of ceilings and partitions. The *floated* and *set* is performed on the rendering in the same manner as it is on the partitions and ceilings of the best kind of plastering, which has been described.

TROWELLED-STUCCO is a very neat kind of work, much used in dining-rooms, vestibules, stair-cases, &c., especially when the walls are to be finished by painting. This kind of stucco requires to be worked upon a floated ground, and the floating should be as dry as possible before the stuccoing is began. When the stucco is made, as before described, it is beaten and tempered with clean water, and is then fit for use. In order to use it, the plasterer is provided with a small *float,* which is merely a piece of half-inch deal, about nine inches long and three inches wide, planed smooth, and a little rounded away on its lower edge; a handle is fitted to the upper side, to enable the workman to move it with ease. The stucco is spread upon the ground, which has been prepared to receive it, with the largest trowel, and made as even as possible. When a piece, four or five feet square, has been so spread, the plasterer, with a brush, which he holds in his left hand, sprinkles a small part of the stucco with water, and then applies the float, alternately sprinkling and rubbing the face of the stucco, till he reduces the whole to a perfect smooth and even surface. The water has the effect of hardening the face of the stucco; so that, when well floated, it feels to the touch as smooth as glass.

CORNICES are plain or ornamented, and sometimes include a portion of both; in the ornamented, superior taste has latterly prevailed, on principles derived from the study of the *antique.* The preliminaries, in the formation of cornices in plastering, consist in the examination of the drawings or designs, and measuring the projections of the members: should the latter be found to exceed seven or eight inches, *bracketing* will be necessary.

BRACKETING consists of pieces of wood fixed up at about eleven or twelve inches from each other, all round the place intended to have a cornice; on these brackets laths are fastened, and the whole is covered with one coat of plastering, making allowance in the brackets for the stuff necessary to form the cornice;

for this about one inch and a quarter is generally found sufficient. When the cornice has been so far forwarded, a mould must be made of the profile or section of the cornice, exactly representing all its members; this is generally prepared, by the carpenters, of beach-wood, about a quarter of an inch in thickness; all the quirks, or small sinkings, being formed in brass. When the mould is ready, the process of running the cornice begins: two workmen are required to perform this operation; and they are provided with a tub of set, or putty, and a quantity of Plaster of Paris; but before they begin with the mould, they guage a straight line, or screed, on the wall and ceiling, made of putty and plaster, extending so far on each as to answer to the bottom and top of the cornice, for it to fit into. This is the guide for moving the mould upon. The putty is then mixed with about one-third of Plaster of Paris, and incorporated in a semi fluid state, by being diluted with clean water. One of the workmen then takes two or three trowels full of the prepared putty upon his hawk, which he holds in his left hand, having in his right hand a trowel, with which he plasters the putty over the parts where the cornice is to be formed; the other workman applying the mould to ascertain where more or less of it is required; and, when a sufficient quantity has been put on to fill up all the parts of the mould, the other workman moves the mould backwards and forwards, holding it up firmly to the ceiling and wall; thus removing the superfluous stuff, and leaving in plaster the exact contour of the cornice required. This is not effected at once, but the other workman keeps supplying fresh putty to the parts which want it. If the stuff dries too fast, one of the workmen sprinkles it with water from a brush.

When the cornices are of very large proportions, three or four moulds are requisite, and they are applied in the same manner until the whole of their parts are formed. The mitres, internal and external, and also small returns or breaks, are afterwards modelled and filled up by hand.

Ornamental Cornices are formed previously, and in a similar way to those described, excepting that the plasterer leaves indents or sinkings in the mould for the casts to be fixed in. The plasterers of the present day cast all their ornaments in Plaster of Paris; whereas they were formerly the work

of manual labour, performed by ingenious men, then known in the trade as *ornamental-plasterers.* The casting of ornaments in moulds has almost superseded this branch of the art; and the few individuals now living, by whom it was formerly professed, are chiefly employed in modelling and framing of moulds.

All the ornaments which are cast in Plaster of Paris, are previously modelled in clay. The clay-model exhibits the power and taste of the designer, as well as that of the sculptor. When it is finished, and becomes rather firm, it is oiled all over, and put into a wooden frame. All its parts are then retouched and perfected, for receiving a covering of melted wax, which is poured warm into the frame and over the clay-mould. When cool, it is turned upside down, and the wax comes easily away from the clay, and is an exact reversed copy. In such moulds are cast all the enriched mouldings, now prepared by common plasterers. The waxen models are made so as to cast about one foot in length of the ornaments at a time; this quantity being easily removed out of the moulds, without the danger of breaking.

The casts are all made with the finest and purest Plaster of Paris, saturated with water. The casts, when first taken out of the moulds, are not very firm, and are suffered to dry a little, either in the air, or in an oven adapted for the purpose; and when hard enough to bear handling, they are scraped and cleaned up for the workmen to fix in the places intended.

The FRIEZES and BASSO-RELIEVOS are performed in a manner exactly similar, except that the waxen moulds are so made as to allow of grounds of plaster being left behind the ornaments, half an inch, or more, in thicknesses; and these are cast to the ornaments or figures, which strengthen and secure the proportions.

CAPITALS to columns are prepared in a similar way, but require several moulds to complete them. The Corinthian capital will require a shaft or bell to be first made, exactly shaped, so as to produce graceful effects in the foliage and contour of the volutes; all of which, as well as the other details, require separate and distinct reversed moulds when intended for capitals made to order.

The plasterers, as before-mentioned, in forming cornices, in which ornaments are to be used, take care to have projections in the running moulds; which have the effect of grooves or indents in the cornices; and into these grooves are put the ornaments after they are cast, which are fixed in their places by having small quantities of liquid Plaster of Paris spread at their backs. Friezes are prepared for cornices, &c., in a similar way, by leaving projections in the running moulds, at those parts of the cornices where they are intended to be inserted, and they are also fixed in their places with liquid plaster. Detached ornaments, when designed for ceilings, or any other parts, to which running moulds have not been employed, are cast in pieces exactly corresponding with the designs, and are fixed upon the ceilings, or other places, with white-lead.

Plasterers require numerous models in wood, and very few or any of their best works can be completed without them. But, with moulds, good plasterers are capable of making the most exquisite mouldings, possessing sharpness and breadths unequalled by any other modes now in practice. This, however is, in some measure, dependent on the truth of the moulds. Good plastering is known by its exquisite appearance, as to its regularity, correctness, solid effect, and without any cracks or indications of them.

ROMAN CEMENT, or OUTSIDE STUCCO.—The qualities of this valuable cement is now generally known in every part of the *United Kingdom.* It was first introduced to public notice by the late JAMES WYATT, Esq. eminent for having planned and executed some of the most magnificent and useful structures in these countries. It was originally known as *Parker's Patent Cement*, and was sold by Messrs. Charles Wyatt and Co., Bankside, London, at *five shillings* and *sixpence* per bushel: it is now vended by different manufacturers in the Metropolis at *three shillings* per bushel, and even less, when the casks are returned. Equal quantities of this cement and sharp clean grit-sand, mixed together, will form very hard and durable coverings for the outsides of public and private edifices. If the sand is wet or damp, the composition should be used immediately. When the works are finished, they should be frescoed, or coloured, with washes, composed in proportions of five ounces

of copperas to every gallon of water, and as much fresh lime and cement as will produce the colours required. Where these sorts of works are executed with judgment, and finished with taste, so as to produce picturesque effects, they are drawn and jointed to imitate well-bonded masonry, and the divisions promiscuously touched with rich tints of umber, and occasionally with vitriol; and, upon these colours mellowing, they will produce the most pleasing and harmonious effects; especially if dashed with judgment, and with the skill of a painter who has profited by watching the playful tints of nature, produced by the effects of time in the mouldering remains of our antient buildings.

The following are the average prices for Roman Cement, as charged in the Metropolis, at per yard superficial.

| | *s.* | *d.* |
|---|---|---|
| Roman Cement, on the outsides of buildings, including all materials, and colouring in the manner described | 4 | 9 |
| Ditto, without colouring | 4 | 0 |
| Ditto, on strong laths | 5 | 3 |
| Plain fascias, pilasters, and belting-courses, or strings, per foot super | 0 | 6 |
| Plain cornices, ditto | 2 | 2 |
| Sinkings, per foot run | 0 | 5 |
| Arris', ditto | 0 | 2 |
| Nine-inch reveals to windows, ditto | 0 | 8 |
| Four inches and a half reveals, ditto | 0 | 5 |

Where the works are circular, *one-fourth, one-fifth,* or *one-sixth,* should be added to the above prices, in proportions to the quickness of the curvatures.

The expenses of dubbing-out, to make the works fair, must be added to the before-mentioned prices; also the value of the cement consumed in performing the same; together with all the time in erecting and taking down the scaffolding; as, also, the expenses of iron spikes, for twine, and other requisite materials, for creating extra projections to cornices, pilasters, &c.

One bushel of cement, used with discretion, care, and judgment, will perform from three to four yards superficial; that is, mixed with an equal portion of clean sharp grit-sand; and, in procuring the latter article, great pains should be taken to select such qualities as are of a lively and binding description, and free from all slime or mud. As soon as the sand and cement is mixed with clean water, the composition should be used as quick as possible, and not a moment lost in floating the walls, which will require incessant labour, until the cement is set, which is almost instantaneous.

ROUGH-CASTING is an outside finishing cheaper than stucco. It consists in giving the wall to be rough-casted a pricking-up coat of lime and hair; and when this is tolerably dry, a second coat of the same material, which is laid on the first, as smooth and even as can be. As fast as this coat is finished, a second workman follows the other with a pail of rough-cast, which he throws on the new plastering. The materials for rough-casting are composed of fine gravel, with the earth washed cleanly out of it, and afterwards mixed with pure lime and water, till the entire together is of the consistence of a semi-fluid; it is then spread, or rather splashed, upon the wall by a float made of wood. This float is five or six inches long, and as many wide, made of half-inch deal, to which is fitted a rounded deal handle. The plasterer holds this in his right hand, and in his left a common whitewash brush; with the former he lays on the rough-cast, and with the latter, which he dips in the rough-cast, he brushes and colours the mortar and rough-cast that he has spread, to make them, when finished and dry, appear of the same colour throughout.

SCAGLIOLA.—The practice of forming columns with Scagliola is a distinct branch of plastering. It originated in Italy, and was thence introduced into France, then into England. For its first introduction here our country is indebted to the late Henry Holland, Esq. who was for many years the favourite architect of his present Majesty, who caused artists to be invited from Paris to perform such works in Carlton-Palace; some of whom, from finding a considerable demand for their works, remained with us, and taught the art to our British workmen.

In order to execute columns and their antæ, or pilasters, in Scagliola, the following remarks and directions are to be observed: when the architect has furnished the drawing, exhibiting the diameter of the shafts, a wooden cradle is made, about two and a half inches less in diameter than that of the projected column. This cradle is lathed all round, as for common plastering, and afterwards covered by a pricking-up coat of lime and hair: when this is quite dry, the workers in Scagliola commence their peculiar labour.

The Scagliola is capable of imitating the most scarce and precious marbles; the imitation taking as high a polish, and feeling to the touch as cold and solid as the most compact and dense marble. For the composition of it the purest gypsum must be broken in small pieces, and then calcined till the largest fragments have lost their brilliancy. The calcined powder is then passed through a very fine sieve, and mixed up with a solution of Flanders glue, isinglass, &c., with the colours required in the marble they are about to imitate.

When the work is to be of various colours, each colour is prepared separately, and they are afterwards mingled and combined nearly in the same manner as a painter mixes, on his pallet, the primitive colours which are to compose his different shades. When the powdered gypsum, or plaster, is prepared, and mingled for the work, it is laid on the shaft of the column, &c., covering over the pricked-up coat, which has been previously laid on it, and is floated, with moulds of wood, to the sizes required. During the floating, the artist uses the colours necessary for the marble intended to be imitated, which thus become mingled and incorporated in it. In order to give his work the polish or glossy lustre, he rubs it with a pumice-stone, and cleanses it with a wet sponge. He next proceeds to polish it with tripoli and charcoal, and fine soft linen; and, after going over it with a piece of felt, dipped in a mixture of oil and tripoli, finishes the operation by the application of pure oil.

This is considered as one of the finest imitations in the world; the Scagliola being as strong and durable as real marble for all works not exposed to the

effects of the atmosphere, retaining its lustre as long and equal to real marble, without being one-eighth of the expense of the cheapest marble imported.

COMPOSITION.—Besides the composition, before adverted to, for covering the outsides of buildings, plasterers use a finer species of composition for inside ornamental works. The material alluded to is of a brownish colour, exceedingly compact, and, when completely dry, very strong. It is composed of powdered whitening, glue in solution, and linseed-oil; the proportions of which are, to two pounds of whitening one pound of glue, and half a pound of oil. These are placed in a copper and heated, being stirred with a spatula till the whole becomes incorporated. It is then suffered to cool and settle; after which it is taken and laid upon a stone, covered with powdered whitening, and beaten till it becomes of a tough and firm consistence. It is then put by for use, and covered with wetted cloths to keep it fresh.

The ornaments to be cast in this composition are modelled in clay, for common plastering, and afterwards carved in a block of box-wood. The carving must be done with great neatness and truth, as on it depends the exquisiteness of the ornament. The composition is cut with a knife into pieces, and then closely pressed by hand into every part of the mould; it is then placed in a press, worked by an iron screw, by which the composition is forced into every part of the sculpture. After being taken out of the press, by giving it a tap upside down, it comes easily out of the mould. One foot in length is as much as is usually cast at a time; and when this is first taken out of the mould, all the superfluous composition is removed by cutting it off with a knife; the waste pieces being thrown into the copper to assist in making a fresh supply of composition.

This composition, when formed into ornaments, is fixed upon wooden or other ground, by a solution of heated glue, white-lead, &c. It is afterwards painted or gilded, to suit the taste and style of the work for which it is intended.

## PLASTERER'S MEASURING AND VALUATION.

The *measuring* and *valuation* of plasterer's work is conducted by surveyors. All common plastering is measured by the yard square, of nine feet; this includes the partitions and ceilings of rooms, stuccoing, internally and externally, &c. &c. Cornices are measured by the foot superficial, girting their members to ascertain their widths, which, multiplied by their lengths, will produce the superficial contents. Running measures consist of beads, quirks, arris's, and small mouldings. Ornamental cornices are frequently valued in this way; that is, by the running foot.

The labour in plasterer's work is frequently of more consideration than the materials; hence it becomes requisite to note down the exact time which is consumed in effecting particular portions, so that an adequate and proper value may be put upon the work.

# CHAPTER X.

## AN EXPLANATION OF TERMS, AND DESCRIPTION OF TOOLS, USED IN BRICKLAYING AND PLASTERING.

Angle Float. See *Float.*

Bass.—A short trough for holding mortar, when tiling the roof: it is hung to the lath.

Bastard Stucco. See *Stucco.*

Bay.—A strip or rib of plaster between screeds, for regulating the floating rule. See *Screeds.*

Bed of a Brick.—The horizontal surface as disposed in a wall.

Bedding Stone.—A straight piece of marble used to try the rubbed side of a brick.

Bricklayer's Tools.—The principal tools used by bricklayers are represented in *plate* XC. The *Brick-trowel, (fig.* 1,*)* is used for taking up and spreading mortar, and likewise for cutting bricks to any required size: this last use renders it necessary that they should be made of the best steel, well tempered.

The *Hammer* used by bricklayers *(fig.* 7,*)* is adapted either for driving, or dividing bricks, and for cutting holes in brick-work, &c. To suit it for these different purposes, one end of the head is formed like the common hammer; and the other end is furnished with a kind of axe, similar to that used by carpenters, only much narrower in proportion to its length. The handle is

# BRICKLAYERS TOOLS.


Engraved by W. Symns.

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placed much nearer to the striking than to the cutting part of the head. The hammer employed for dividing and pulling down old brick walls, instead of the axe part, more nearly resembles an adze, but is not so broad in porportion to its length.

The *Plumb Rule* is about four feet in length, and it is furnished with a line and plummet, to direct the workman in carrying up walls vertically. It consists of a well-seasoned board, of moderate thickness and breadth, and about four feet long. Down the middle of one side of this board a straight line is drawn, so that a cord which is fastened to the top, equi-distant from the arris on each side of it, may hang straight therein. To this cord a weight is attached, in order to shew the inclination of the cord more correctly, and a hole is cut in the bottom to admit it. The workman, in order to carry up his wall perpendicularly, applies either of the sides of this rule to the wall, so that the plummet and its cord may face him; and if the cord of the plummet does not coincide with the line on the rule, before the mortar becomes dry, he sets the bricks farther in or out, according to circumstances.

The *Level*, used by bricklayers, is similar to that of the carpenter, described in page 233. Its length varies from six to twelve feet. If to the middle of a long narrow edge of a board of the same thickness, but about double the length of the plumb-rule, one end of the plumb-rule were joined at right angles, as the lower edge or side of the piece thus added to the rule would become the surface placed on walls, to ascertain whether they are horizontal or not, the plumb-line would thus become a level. The correctness of a level is determined by placing it vertically on any flat surface, and lowering or raising the support till the cord of the plummet exactly coincides with the line on the perpendicular rule. When this is done, reverse the ends, and if the same effect takes place, the level is true; but if it does not, the bottom of the board must be shot, till this coincidence takes place. The perpendicular and horizontal parts of the level are not only fastened together by a tenon and mortise, but two braces are likewise added, in a slanting direction, from the horizontal piece nearly to the top of the perpendicular one, in order to give it greater firmness.

The *Large Square* is employed for setting out the sides of a building at right-angles.

The *Small Square, (fig.* 3,*)* is used for trying the bedding of bricks, and squaring the soffits across their breadth.

The *Bevel, (fig.* 4,*)* is employed in drawing the soffit line on the face of the bricks.

The *Rod* is from five to ten feet in length, and is used for measuring lengths, heights, and breadths, with more facility than could be done by a pocket-rule. The feet are divided by notches, and one of those next to the extremity of the rod is subdivided into inches.

The *Measuring-Tape* is a kind of strong tape, graduated, marked, and coiled up by a little winch into a cylindrical box; and thus it unites the portableness of the pocket-rule, with the greater despatch of the rod.

The *Jointing-Rule (fig.* 5,*)* is about eight or ten feet long, and about four inches broad. It is used for running the joints of brick-work. When it is designed for the use of two bricklayers, the latter length is employed.

The *Jointer (fig.* 6,*)* is an iron tool, used along with the jointing-rule, to mark the joints of brick work horizontally and vertically. Its form nearly resembles an ∽, with less flexure in proportion.

The *Raker, (fig.* 8,*)* is a piece of iron, pointed with steel, with two knees or angles, so as to resemble a Z, if the connecting stroke of the top and bottom were perpendicular instead of slanting; so that the pointed parts are of equal lengths, and stand at contrary sides of the middle part. It is used to pick or rake loose and decayed mortar out of the joints of old walls, that are intended to be re-filled with new mortar, or fresh pointed.

The *Hod* resembles the half of a rectangular box, divided so as to consist of two boards at right angles to each other, and a third board to shut up one end. From the middle of the angular ridge, formed by the meeting of the two sides, projects the handle, which is a pole of about four feet long. That part of the ridge which is between the back or end board, is generally covered with several thicknesses of leather; or with leather stuffed with wool, in order that the angle of the ridge may not cut the shoulder of the labourer.

This utensil is used for carrying bricks or mortar for supplying the bricklayer. When used for mortar, it is customary to strew the internal surface of the hod with clean dry sand, to prevent the mortar from adhering to the wood.

The *Line Pins, (fig.* 9,*)* consist of two iron pins, with a line of about sixty feet, fastened by one of its extremities to each. It is used by being stretched close to the wall, and removed at proper intervals as the work advances, in order to guide the workmen in laying the different courses of bricks exactly straight.

The *Rammer,* used by bricklayers, *(fig.* 10,*)* is similar to that of paviors, and it is used for ascertaining whether ground is sufficiently strong to bear a foundation. It is also used for giving unstable ground its proper degree of compression, in order to prevent fractures in the walls; which would naturally ensue, if the foundation were laid when the ground is in a loose state.

The *Iron Crow* is a long bar of iron used for breaking through old walls, or raising heavy bodies out of the ground.

The *Pick-axe, (fig.* 11,*)* consists of a long bar of iron, of considerable thickness in the centre, which is furnished with a hole or mortise for receiving a handle. The two arms on the sides of the centre and handle generally diminish or taper considerably towards their extremities, in order that their points may more readily enter the earth in digging; or be inserted between bricks or stones to separate them. The arms, likewise, incline towards the handle, so as to form the segment of a circle. The pick-axe is frequently used in conjunction with the iron crow.

The *Compasses,* used by the bricklayer, are similar to those used by the carpenter and joiner, and are employed for traversing arches.

The *Grinding-Stone* is used for sharpening axes, hammers, &c., and scarcely, perhaps, requires to be mentioned.

The *Scribe* is a pike, or large nail, ground to a sharp point, and used for marking the bricks in the part where they are to be cut.

The *Chopping-block* is made of any chance piece of wood that can be obtained, of about six or eight inches square, when for two men to work

thereon; and lengthened in proportion for four or more. It is generally supported, about two feet three inches from the ground, upon two or more fourteen-inch brick piers. It is better to have several blocks when they can be obtained, in preference to allowing many hands to be employed at one; because the vibrations communicated by one workman are liable to inconvenience another.

The Chopping-block is used for reducing bricks to any required form by means of the axe.

The *Banker (fig. 13,)* is a bench, from six to twelve feet in length, according to the number of men it is intended to accommodate; from two to three feet in breadth, and about one inch thick. An old ledged door may easily be converted into a banker, by placing its back edge against a wall, and supporting the front with three, four, or five posts: it is used for rubbing and guaging bricks for arch-work. B, in the figure, represents the rubbing-stone.

The *Camber-slip (fig. 12,)* is a piece of board of any length or breadth, made convex on one or both edges, and generally something less than an inch in thickness: it is made use of as a rule. When only one side or edge is cambered, it rises about one inch in six feet, and is employed for drawing the soffit lines of straight arches: when the other edge is curved, it rises only about one half of the other, *viz.* about half an inch in six feet, and is used for drawing the upper side of the arch, so as to prevent its becoming hollow by the settling of the arch. But some persons prefer having the upper side of the arches straight; and, in this case, the upper edge of the arch is not cambered. When the bricklayer has drawn his arch, he gives the camber-slip to the carpenter, who by it forms the centre to the curve of the soffit. The bricklayer, in order to prevent the necessity of having many camber-slips, should always be provided with one which is sufficiently large for the widest aperture likely to be arched.

The *Mould* is used for forming the face and back of the brick to its proper taper; and, to this end, one edge of the mould is brought close to the bed of the brick previously squared. The mould has a notch for every course of the arch.

The *Templet* is an instrument for taking the length of the *stretcher* and the width of the *header*, in building walls, &c.

The *Tin Saw* is used for cutting, to about the eighth of an inch deep, the soffit lines made, first by the edge of the bevel on the face of the brick, and then by the edge of the square on the bed of the brick. This incision is made in order to form an entrance for the brick-axe, that it may reduce the bricks to the proper form for arches, without splintering or jagging their edges. This saw is likewise used for cutting the false joints of headers and stretchers.

The *Brick-axe* is used for reducing or cutting off the soffits of bricks to the saw-cuttings, and the sides to the lines drawn by the scribe. Much of the labour required for rubbing the bricks may be removed by the axe being managed with dexterity.

The *Rubbing-Stone*, B, *(fig.* 13,*)* is a rough grained stone, of about twenty inches in diameter, generally fixed at one end of the banker, on a bed of mortar. It is used for smoothing those bricks which have been brought to their proper form by the axe. The headers and stretchers in returns, which are not axed, are likewise dressed upon the rubbing-stone. If the grain of the stone is found not to be sufficiently sharp to reduce the bricks with the necessary expedition, a little sand will tend to remove this deficiency.

The *Bedding-Stone* consists of a marble slab, from eighteen to twenty inches in length, and from eight to ten wide, and of any thickness. It is used to try whether the surface of a brick, which has been already rubbed, be straight, so that it may fit upon the leading skew back, or leading end of the arch.

The *Float-stone* is used for taking out the axe-marks, and smoothing the surfaces of curved work, as the cylindrical backs and spherical heads of niches. But, for this purpose, the Float-stone must itself be curved in the reverse form, though of a radius equal to that intended for the brick, so that it may coincide, as nearly as possible, with the brick.

CEILING.—The upper side of an apartment, opposite to the floor, generally

finished with plastered work. Ceilings are set in two different ways, the best is where the setting coat is composed of plaster and putty, commonly called *guage.*

Clinker.—A portion of a brick, used where the distance will not permit a whole one in length.

Coarse Stuff. See *Lime* and *Hair.*

Coat.—A stratum, or thickness, of plaster-work, done at one time.

Compo, or *Compos,* used in outside stucco-work, implies the materials with which Roman or any other similar cement is composed: that is, when the component parts are all incorporated. To ascertain their different qualities, the same must be decomposed, or analysed.

Course.—A horizontal stratum, layer, or row, of bricks, extending along the whole length of a wall.

Derby.—A two-handed float.

Die.—Plaster is said to die when it loses its strength.

Dots.—Patches of plaster put on to regulate the floating-rule in making screeds and bays.

Fine Stuff, for plastering, is made of lime slaked and sifted through a fine sieve, and mixed with a due quantity of hair, and sometimes a small quantity of fine sand.

Finishing, in plastering, is the best coat of three-coat work, when done for stucco. The term *setting* is commonly used, when the third coat is made of fine stuff for papering.

First Coat, of two-coat work, in plastering, is denominated *laying* when on lath, and *rendering* when on brick: in three-coat work upon lath it is denominated *pricking-up;* and upon brick, *roughing-in.*

Float.—An implement used in plastering for forming the second coat of three-coat work to a given form of surface.—An *Angle-Float* is a float made to any internal angle to the planes of both sides of a room. The *Derby* is a two-handed float.

Floated Lath and Plaster, set fair for paper, is three-coat work; the first *pricking-up,* the second *floating,* and the third, or *setting coat* of fine-

stuff, understood to be *pricked-up,* as there is no floated work without pricking-up.

Floated, Rendered, and Set.—A common term explained in the previous definitions.

Floated Work, in plastering.—That which is pricked-up, floated and set, or roughed-in.

Floating, in plastering.—The second coat of three-coat work.

Floating-Rules, used by plasterers, have been already noticed. They are of every size and length.

Floating-Screed, in plastering, differs from cornice-screeds, in this, that the former is a strip of plaster, and the latter wooden rules for running the cornice. See *Screed.*

Gauge, in plastering.—A mixture of fine-stuff and plaster, or of coarse-stuff and plaster, used in finishing the best ceilings, and for mouldings, and sometimes for setting walls.

Hawke.—A board, with a handle projecting perpendicularly from the underside, for holding plaster.

Laths.—Small slips of wood nailed to rafters, for hanging the tiles or slates upon. For laths used in plastering, see page 372.

*Double Fir Laths* are laths three-eighths of an inch thick, single laths being a bare quarter, or less than a quarter of an inch.

Lath, Floated and Set Fair.—These words bear the same meaning as lath pricked-up, and floated and set, to which the reader is referred.

Lath, Layed and Set, in plastering, is two-coat work; only the first coat, called *laying,* is put on without scratching, unless it be with the points of a broom. This is generally coloured on walls, and whited on ceilings.

Lath, Plastered, Set, and Coloured, is the same with lath, layed, set, and coloured, to which the reader is also referred.

Lath, Pricked-up, Floated and Set, for Paper, is three-coat work; the first is *pricking-up,* the second *floating,* and the third the *finishing* of fine-stuff.

Laying, in plastering.—The first coat on lath of two-coat plaster, or *set-work.* It is not scratched with the scratcher; but its surface is roughed

by sweeping it with a broom; it differs only from *rendering* on its application. *Rendering* is applied to the first-coat work upon brick; whereas *laying* is the first of two-coat work upon lath.

Laying on Trowels.—The trowels used for laying on plaster.

Lime and Hair, in plastering.—A mixture of lime and hair used in first-coating and in floating: it is otherwise denominated *coarse-stuff*. In floating, more hair is used than in first-coating.

Mitering Angles.—Making good the internal and external angles of mouldings.

Mortar.—A preparation of lime and sand mixed with water, and used as a cement, as already explained in pages 329, 371, &c.

Mouldings, in plastering.—When not very large, mouldings are first run with coarse guage to the mould, then with fine-stuff, then with putty and plaster, and, lastly, run off, or finished, with raw putty. When mouldings are large, coarse-stuff is first put on, then it is filled with tile-heads or brick-bats, and run off successively with coarse gauge, fine-stuff gauge, putty guage, and finished with raw putty. In running cornices, there must always be screeds upon the ceiling, whether the ceiling is floated or not.

Pargeting.—A term derived from *parget*, or the plaster-stone, and used for the plastering of walls; sometimes for the plaster itself.

Plaster.—The material with which ornaments are cast, and with which the fine-stuff of guage for mouldings and other parts are mixed.

Pricking-up, in plastering.—The first coating of three-coat work upon laths. The material used is coarse stuff, sometimes, in London, mixed up with drift road sand, scrapings, or Thames sand, and its surface is always scratched with an instrument used for that purpose.

Pugging.—The materials composed of bricks and mortar, &c. introduced between the joists of floors, in order to prevent the communication of sound, or to deaden it in the interval from one story to another.

Putty.—A very fine cement, made of lime only.

Rendered and Floated, in plastering, is three-coat work, more commonly called *floated, rendered,* and *set*.

RENDERED, FLOATED, and SET, for paper, should be termed *roughed-in.* Floated and set, for paper, is three-coat work; the first, lime and hair upon brick-work; the second, the same stuff, with a little more hair, floated with a long rule; the last, fine stuff, mixed with white hair.

RENDERED and SET.—The same as set-work. See *Set-work.*

ROUGH-CAST.—The overlaying of walls with mortar, without smoothing it with any tool whatever. This has been already noticed. See page 380.

ROUGHING-IN, in plastering.—The first coat of three-coat work.

ROUGH-RENDERING, in plastering, means one coat rough.

ROUGH-STUCCO. See *Stucco.*

SAIL-OVER.—A term denoting the over-hanging of one or more courses of bricks beyond the naked of the wall.

SECOND COAT, in plastering.—Either the finishing coat, as in layed and set, or in rendered and set; or it is the floating, when the plaster is roughed-in, floated, and set, for paper.

SCREEDS.—Wooden rules for running mouldings, and also the extreme guides upon the margins of walls and ceilings for floating.

SET-FAIR.—A term in plastering, used after roughing-in and floated, or pricked-up and floated work.

SETTING.—The quality that any kind of stuff has to harden in a short time.

SETTING-COAT, on ceilings or walls, in the *best* work, is guage, or a mixture of putty and plaster; but in common work it consists of fine-stuff.

SET-WORK, in plastering.—Two-coat work upon lath.

SKEW-BACK.—The sloping abutment for the arched head of a window.

STOPPING.—Making good apertures and cracks in the plaster.

STUCCO, or FINISHING.—The third coat of three-coat plaster. Rough Stucco is that which is finished with stucco, floated, and brushed.

BASTARD STUCCO.—Three-coat plaster, the first generally *roughing-in,* or rendering; the second *floating,* as in *trowelled-stucco;* but the finishing coat contains a little hair besides the sand. It is not *hand-floated,* and the trowelling is done with less labour than what is denominated *trowelled-stucco.*

THIRD COAT, in plastering.—The *stucco* for paint, or *setting* for paper.

Three-coat Work, in plastering, is that which consists of pricking-up, or roughing-in, floating, and a finishing coat.

Tools, Bricklayers'. See *Bricklayers' Tools,* pages 384, &c.

Tools, Plasterers. See pages 370, 371, &c.

Toothings.—Bricks projecting at the end of a part of a wall, to bond a part of the said wall, not yet carried up.

Traversing the Screeds for Cornices, is putting on gauge-stuff on the ceiling screeds, for regulating the running mould of the cornice above.

Trowelled-stucco, for paint.—The same as roughed-in for brick-work.

Two-coat Work, in plastering, is either layed and set, or rendered and set. See those articles.

Water Table.—The bricks projecting below the naked of a wall to rest the upper part firmly upon.

Work.—The coating of plaster layed and set, and applied to brick-work where there are two coats only.

# CHAPTER XI.

## SLATING,

### WITH AN EXPLANATION OF TERMS, &c.

SLATING, till lately, was employed only for covering the roofs of buildings; but it is now used for forming balconies, chimney-pieces, castings to walls, skirtings, stair-cases, &c.

The slates most in use about London are the Welsh and Westmoreland, but the latter are now almost superseded by the former. About eighty years ago French slates were much used: they are smaller than Welsh slates, and, being very thin, are consequently extremely light; and their thinness renders them liable to be easily penetrated by wet, and are, of course, considered unfit for our climate. Slates of this kind, after they have been long exposed to the atmosphere in these countries, are often shivered in pieces; and they may sometimes be found completely decomposed, or reduced to a powdered state. This imperfection, since it has been known, has prevented their being used in this country; nor is it probable they will be again introduced.

The Welsh Slates are generally classed in the following order.

| | *ft.* | *in.* | | *ft.* | *in.* |
|---|---|---|---|---|---|
| Doubles, average size | 1 | 1 | by | 0 | 6 |
| Ladies | 1 | 3 | — | 0 | 8 |
| Countesses | 1 | 8 | — | 0 | 10 |
| Duchesses | 2 | 0 | — | 1 | 0 |
| Welsh Rags | 3 | 0 | — | 2 | 0 |
| Queens | 3 | 0 | — | 2 | 0 |
| Imperials | 2 | 6 | — | 2 | 0 |
| Patent Slate | 2 | 6 | — | 2 | 0 |

The DOUBLES are so called from their small size. These are made from the fragments of the larger qualities, as they are sorted, respectively.

The LADIES are made up from fragments, as above, in pieces that will square up to the size of such a description of slate.

COUNTESSES are in size the next gradation above *ladies;* and DUCHESSES still larger.

SLATE is extracted from the quarries in the same manner as other stony substances; that is, by making perforations between its beds, into which gunpowder is placed and fused. This opens and divides the beds of the slate, which the quarry-men remove in large blocks. These blocks are afterwards split by wedges of iron, driven between their layers, which separate the blocks into such scantlings as may be required. When slate is to be exported in this state, its edges are sawn to the sizes ordered; for it is not necessary to use the saw to the horizontal stratum of the slate, as that can be divided nearly as correct by the ready method above-mentioned.

The works in Wales, for sawing slate, are furnished with excellent machinery, which is set in motion either by steam or by water, and keeps in action a vast number of saws, each sawing the scantlings of slate into pieces adapted to their respective purposes.

The IMPERIAL SLATING, for roofs, is particularly neat, and is known by having its lower edge sawn; whereas all the other slates, used for covering, are only chipped square on their edges.

PATENT SLATING is so called, among the slaters, from the peculiar mode of laying it on roofs, but we are not aware of any patent for it being ever obtained. It was first brought into notice by the late James Wyatt, Esq. the architect of our late revered king, George the Third. Patent slating may be laid on rafters of much less elevation than any other kind of slating; it is considerably lighter; because the breadths of the laps are much less than the slates adopted for the common sort of slating. Patent slating was originally composed of slates called the *Welsh Rags,* but at the present time it is composed of the *Imperials,* which are lighter, and much neater in appearance.

On the WESTMORELAND SLATE some experiments were made by Dr. Watson, the late Bishop of Llandaff, whence it appears that there is very little

difference in the natural composition of this kind of slate and that of Wales. The Bishop's comparison of their absolute weight, as compared with the weight of other materials made use of as a covering to buildings, may be of great utility, inasmuch as it may tend towards forming a datum for adding to, or diminishing from, the quantity of timber employed in roofs of different spans and elevations. "That sort of slate," says his lordship, "other circumstances being the same, is esteemed the best, which imbibes the least water; for the imbibed water not only increases the weight of the covering, but, in frosty weather, being converted into ice, it swells and shivers the slate. This effect of the frost is very sensible in tiled houses, but it is scarcely felt in slated ones; for good slate imbibes but little water; and, when tiles are well glazed they are rendered, in some measure, with respect to this point, similar to slate." He adds, "I took a piece of Westmoreland slate and a piece of common tile, and weighed each of them carefully; the surface of each was about thirty square inches; both the pieces were immersed in water for ten minutes, and then taken out and weighed as soon as they had ceased to drip, and it was found that the tile had imbibed about one-seventh part of its weight of water, and the slate had not imbibed a two-hundredth part of its weight. Indeed the wetting of the slate was merely superficial, while the tile, in some measure, became saturated with the water. I then placed both the wet pieces before the fire; in a quarter of an hour's time the slate was become quite dry, and of the same weight it had before it was put into the water; but the tile had lost only about twelve grains of the water it had imbibed, which was, as near as could be expected, the same quantity that had been spread on its surface; for it was this quantity only which had been imbibed by the slate, the surface of which was equal to that of the tile. The tile was left to dry in a room heated to 60° of Fahrenheit, and it did not lose all the water imbibed in less than six days." He adds, further, "that the finest sort of Westmoreland slate is sold at Kendal at 3*s.* 6*d.* per load, which will amount to 1*l.* 15*s.* per ton, the load weighing two hundred weight. The coarser sort may be had at 2*s.* 4*d.* a load, or 1*l.* 3*s.* 4*d.* per ton. Thirteen loads of the finest sort will cover forty-two square yards of roofing, and eighteen loads of the coarsest will cover the same quantity;

so that there is half a ton less weight put upon forty-two square yards of roofs, when the finest sort of slate is used, than if it was covered with the coarsest kind, and the difference of expense only three shillings and sixpence." It must be remarked, that this slate owes its lightness, not so much to any diversity in the component parts of the stone from which it is split, as to the thinness to which the workmen reduce it, and it is not so well calculated to resist violent winds as that which is heavier.

## COMPARISON IN WEIGHT OF THE SUNDRY COVERINGS EMPLOYED ON ROOFS.

A *Common Plain Tile* weighs thirty-seven ounces, and they are used, at a medium, seven hundred to cover a single square of roof of one hundred superficial feet.

A *Pan-tile* weighs seventy-six ounces, or four pounds and three-quarters, and one hundred and eighty are required to lay on a single square of roof.

Both the plain and pan tiles are commonly bedded in mortar; indeed the former cannot be well laid on a roof without it. The mortar used may be about one-fourth of the weight of the tiles.

Common lead or copper, for covering roofs, generally requires seven pounds of the former, and seven ounces of the latter, for each superficial foot. A square of one hundred feet covered with the above materials stand relatively thus:

| | *cwt.* | *qrs.* | *lbs.* |
|---|---|---|---|
| For Copper, per square | 0 | 3 | 16 |
| Lead | 6 | 1 | 0 |
| Fine Slate | 6 | 0 | 21 |
| Coarser ditto | 8 | 1 | 8 |
| Plain Tiles | 18 | 0 | 0 |
| Pan-Tiles | 9 | 2 | 0 |

Hence a careful builder may select such a covering as his building may be best adapted to support.

## OF THE MANNER OF LAYING SLATES.

All kinds of slate have a *lap* of each joint, generally equal to one-third of the length of the slate. The largest slates are reserved for the eaves. The slater, first picking and examining the slates to discover the strongest and squarest end, holds the slate over the edge of a small block of wood, cuts one of its edges straight, and having gauged the other thereby, cuts off that also; and, making two small holes on its opposite side, finishes the slate for the roof. All quarry slates require this preparation from the slater. The above holes are for the reception of the nails intended to fasten the slates to the roof. The copper and zinc nails are esteemed the best. When iron nails are used, they should be previously put into a tub of fluid white lead, till they are completely covered, and then left to dry. Iron nails, plated with tin, have lately been introduced, and are much cheaper than copper ones.

A base or floor is laid for receiving the slates. Boarding is essential for Doubles and Ladies, and this should be laid with even joints and well nailed down to the rafters. Then the slater, having provided himself with slips of wood, two inches and a half wide and one inch thick on one side, and chamfered away to an arris on the other, nails down these *tilting fillets*, as they are called, beginning with the hips, then the sides, eaves, and ridge. He next lays the eaves, setting their lower edge to a line, and nails them down to the boarding. A bond is then formed to the under sides of the eave, by placing another row under, so as to cross all the joints; this row is not nailed, but tightly pushed up and left dependent for support on the pressure of those above them and their own weight on the boarding. The slater then draws a straight line on the upper part of the row laid for a bond, and lays another course of slate crossing the joints of the other, and nails them down even with the line marked. This process is repeated till the whole roof is finished. All the larger kinds of slate may be made to lay upon battens, which saves an expense of about twenty shillings per square. A *batten* is a narrow piece of deal, about two inches and a half or three

inches wide. For *Countesses* the bottoms may be about three-quarters of an inch thick, but for the larger kind of slate they should be an inch. The slater is the fittest person to lay them, as he may thus suit the length of his slates, and other particulars, which he best understands. This is the general method of laying all kinds of slate, except the *patent slating.*

The PATENT SLATING, so called, consists of the largest slates of an uniform thickness; *Imperials* are now generally taken. Neither battens nor boarding is required for these slates; but the common rafters should be left loose on the purlins, so that a rafter may be fixed under each of the meeting joints of the rows of slates. The work of covering is then performed, as above described, except that no bond is required, the slates being laid uniformly, and screwed down by two or three strong one and a half inch screws at each end into the rafters beneath.

*Filleting* is now commenced, which consists in covering the meeting-joints with fillets of slates, bedded in putty, and screwing them down through the whole into the rafters. These fillets are then neatly pointed up with more putty, and then painted, to resemble the slates. The hips and ridges of roofs are sometimes filleted, but lead is preferable. The Patent Slating may thus be laid, perfectly water-tight, with a rise of two inches in one foot of a rafter.

These are the general modes of laying slates; and for peculiar neatness they are sometimes laid in a lozenge form, but as, in this form, only one nail can be used to each slate, thus laid they soon become dilapidated.

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The SLATERS' TOOLS are the *Saixe, Ripper, Hammer, Shaving-Tool,* and various kinds of *Chisels, Guages,* and *Files.*

The SAIXE is of steel, and not unlike a large knife, except having on its back a piece of iron, projecting about three inches, and drawn sharp to a point. It has a handle of beech, and is used for chipping and cutting slates.

The RIPPER is formed of iron, about the same length as the Saixe, with a very thin blade, tapering towards the top, where a round head projects about half an inch, with two little notches at the intersection of one with the other.

This tool is used for lifting up and removing the nails out of old slating, when it is to be repaired.

The HAMMER differs but little from the common tool of the same name, except that the upper portion of the driving part is higher and bent towards the handle, so as to form a claw, by having a notch in its centre. It is used for extracting nails that do not drive satisfactorily.

The SHAVING TOOL consists of a blade of iron, about eleven inches long and two wide, sharpened at one of its ends, like a chisel, and mortised into two round wooden handles. It is used for smoothing the surface or face of a slate, for skirtings, floors of balconies, &c.

The CHISELS, GAUGES, and FILES, need no description. They are used for finishing the better parts of the slater's work, as mouldings, chimney-pieces, skirtings, casings, &c.

The STRENGTH of SLATE to Portland Stone has been calculated to be as five to one, and consequently slate should be used where lightness is required combined with strength.

## VALUATION OF SLATERS' WORK.

SLATERS' work is measured by Surveyors by the square of 100 feet superficial. Besides the nett dimensions of their work, slaters are allowed six inches for eaves, and four for hips, for common slating; and nine inches in addition for rags or imperials. Slating for roofing may be averaged thus per square.

| | £. | s. | d. |
|---|---|---|---|
| Doubles | 2 | 2 | 0 |
| Countesses | 2 | 12 | 6 |
| Welsh Rags and Imperials | 3 | 13 | 6 |
| Westmoreland | 4 | 14 | 6 |

Slaters' work, for galleries, varies, according to the mouldings, from 4*s*. 6*d*. to 5*s*. 6*d*. per foot superficial; skirtings and facings from 1*s*. 6*d*. to 2*s*. per foot. Chimney-pieces, &c. are sold at so much per piece.

## EXPLANATION OF THE TERMS USED IN SLATING.

Back of a Slate.—The upper side of it.

Backer.—A narrow slate put on the back of a broad square-headed slate when the slates begin to get narrow.

Bed of a Slate.—The lower side of it.

Bond or Lap of a Slate.—The distance between the nail of the under slate, and the lower end of the upper slate.

Eave.—The skirt or lower part of the slating hanging over the naked of the wall.

Holing.—The piercing of slates for the admission of nails.

Margin of a Course.—Those parts of the backs of the slates exposed to the weather.

Nails.—Pointed iron, or copper, or zinc, of a pyramidal form, for fastening the slates to the laths or boarding. They are commonly of the description or shape of Clout-nails.

Patent Slates.—Those which are used without boarding, and screwed to the rafters, with slips of slates, bedded in putty, to cover the joints.

Scantle.—A gauge by which slates are regulated to their proper length.

Sorting.—Regulating slates to their proper length by means of the scantle.

Squaring.—Cutting or paring the sides and bottom of the slates.

Tail.—The bottom or lower end of the slate.

Trimming.—Cutting or paring the side and bottom edges of a slate, the head of the slate never being cut.

# CHAPTER XII.

## PLUMBERY, OR PLUMBING.

THE ART of PLUMBERY comprehends the practice of casting and laying sheet-lead, with the making and forming of pumps, cisterns, reservoirs, water-closets, &c.

The ductility of the metal in which he works enables the Plumber to effect his operations by means of tools, few in number and simple in construction. Of these the principal are as follow:

A HAMMER, which is made of iron, and which differs from the one in common use only in being somewhat heavier.

A JACK-PLANE, which is similar to that used by carpenters, and employed by the plumbers for smoothing the rough parts of the edges of sheet lead.

The TRYING-PLANE is similar to the carpenter's instrument of the same name; and is used for trying or finishing the edges of sheet lead, when they have been already smoothed by the jack-plane.

A CHALK-LINE is a line which, being rubbed on chalk, is used for marking out the lead into the different widths which may be required.

The DRESSING and FLATTING TOOL is made of beech, about eighteen inches long, and two and a half square; planed smooth on one side, and rounded into an arch on the other. It is used for stretching out and flattening the sheet lead, or dressing it into any required shape.

MALLETS are similar to those of the carpenter, and are of various sizes to suit different kinds of work.

Glasing or Heating Irons are of various sizes, generally about twelve inches long and tapering at both ends; the handle end being turned quite round, that it may be held firmly in the hand, and the opposite end spherical or of a spindle shape. They are used red-hot in soldering.

Ladles are of three or four different sizes, and are used for melting the solder.

Chisels are of various sizes, according to the purposes to which they are applied.

Gauges also vary in size according to their uses.

Cutting Knives are of various sizes, and are used for dividing sheet lead at the mark left by the chalk-line.

Files are likewise of various sizes. The name points out their use.

The Measuring Rule is two feet in length, and is divided into three equal parts. Two of these legs are of box-wood, duodecimally divided, and the third of slow tempered steel. Its name points out its use.

Centre-bits are of various sizes, according to the perforation they are intended to make.

Compasses are used for striking out circular portions of lead.

These are the principal tools; but the plumber must also be provided with weights and scales, as most of his work is charged by the weight.

Lead, the metal in which the plumber chiefly works, is distinguished for its durability, maleability, and other properties, which render it of the highest importance. It is of a bluish-white colour, and, when newly melted, very bright, but it soon becomes tarnished by exposure to the air. Its specific gravity is 11,3523. It may be reduced, by the hammer, to very thin plates, and may also be drawn out into wire; but its tenacity is not great if compared with many of the other metals. A lead wire of one hundred and twentieth of an inch diameter is capable of supporting 18·4 pounds only without breaking.

Lead melts when heated to the temperature of 612° of Fahrenheit, and when a stronger heat is applied it boils and evaporates. If it be cooled slowly, it crystallizes. When exposed to the air it soon loses its lustre, and

acquires at first a dirty grey colour; and, finally, by corrosion, its surface becomes almost white.

When taken from the mines, lead is almost always combined with sulphur, and hence it is called a *sulphuret*. The operation of *roasting* the ore, or *smelting*, consists:—1st. In picking up the mineral, to separate the unctuous, rich, or pure, ore, from the stony matrix, and other impurities. 2d. In pounding the picked ore under the stampers. 3d. In washing the pulverized ore to carry off the matrix by the water. 4th. In roasting the mineral in a reverberatory furnace, taking care to stir it, in order to facilitate the evaporation of the sulphur. When the surface begins to have the consistence of paste, it is covered with charcoal; the mixture is shaken, the fire increased, and the lead then flows down on all sides to the bottom of the basin of the furnace, from which it is drawn off into moulds or patterns, prepared to receive it.

The moulds are made so as to take a charge of metal equal to one hundred and fifty-four pounds; these are called, in commerce, *pigs*, or *pigs of lead*.

The plumbers use lead in sheets of two kinds; the one called *cast*, and the other *milled lead*. The cast lead is used for the purpose of covering the flat roofs and terraces of buildings, forming gutters, lining reservoirs, &c. In architecture it is technically divided into 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$, 7, $7\frac{1}{2}$, 8, $8\frac{1}{2}$, lbs. cast-lead; by which is understood, that every foot superficial of such cast-lead is to contain one or other of these weights; so that an architect, when directing a plumber to cover or line a place with cast sheet-lead, tells the workman that it is to be done with 6 or 7lb. lead; meaning by it, that he expects each foot superficial of the metal to be equal in weight to six, seven, or other, number of pounds.

CASTING.—Every plumber, who conducts business to any extent, casts his sheet-lead at home; this he does from the pigs, or from old metal, or both. To perform this he provides a copper, well fixed in masonry, and placed at one end of his *casting-shop*, near to the *mould* or *casting-table*. The casting-table is, generally, in its form, a parallelogram, well jointed, and bound with iron at the ends, and varying in its size from six feet in width to eighteen or more feet in length. It is raised from the ground so high as to be about six or seven inches below the top of the copper, which contains

the metal, and stands on strongly framed legs, so as to be very steady and firm. The top of the table is lined with deal boarding, laid firmly and very even, and it has a rim projecting upwards, four or five inches all round. At the end of the table, nearest to the copper, a box, called the *Pan*, is adapted, which box is equal in length to the width of the table; at the bottom is a long horizontal slit, for the heated metal to issue from. This box moves upon rollers along the edges of the projecting rim of the table, and is set in motion by ropes and pulleys, fixed to beams over the table. So soon as the metal is found to be adequately heated, the bottom of the table is covered by a smooth stratum of dry and clean sand. These boxes are made to contain as much melted lead as will cast the whole of the sheet at the same time, and the slit in the bottom is adjusted so as to let through a sufficient quantity to cover it completely, of the thickness and weight per foot required. When the box has dispersed its contents upon the table, it is suffered to cool and congeal; after which it is rolled up and removed away. Other sheets are made in succession till all the melted metal in the copper be cast up.

The sheets thus formed, when rolled up, are weighed; as it is by the weight that the price is adjusted.

The other kind of sheet-lead made use of by plumbers, and called Milled Lead, is not manufactured at home, it being purchased of the lead merchant, as it is commonly cast and prepared at the ore and roasting furnaces. It is very thin, its weight being not more than four pounds in the foot superficial. Milled Lead is used by architects for covering the hips and ridges of roofs, or any part exposed either to great wear and tear, or to the effects of the sun. It is laminated in sheets of about the same size as that of cast sheet-lead; and, in the operation of making it, a laminating-roller is used, or a flatting-mill, which reduces it to the state in which it is used.

SOLDER is used for uniting the joints of leaden work, and it should more readily acquire a state of fusion than the metal intended to be soldered thereby, and be of the same colour. The solder generally made use of by the plumber is called *soft solder*, and is made of tin and lead, in equal parts, fused together, and run into moulds not unlike a common gridiron. In this state it is purchased of the manufacturer by the plumber, at so much per pound.

LAYING SHEET-LEAD.—The ground for sheet-lead, whether it be of plaster or of boards, should be perfectly even, otherwise the work will be bad, unsightly, and liable to crack. The sheets not being more than six feet in width, make it necessary that they should sometimes be joined. This is performed either by *seams* or *rolls*. The seams are formed by bending the two edges of the lead up and then over each other, and then dressing them down close. The rolls are formed by fastening a piece of wood, about two inches square, under the joints of the lead, and dressing one of the edges of the lead over the roll on the inside, and the other edge over both of them on the outside, and then fastening them down by hammering. Soldering is sometimes used for joining two sheets, but no good plumber would recommend it, as it always cracks after being exposed to one summer's sun. All sheet lead is laid with a *current* to keep it dry. This is done by the carpenter raising the boarding about one half or a quarter of an inch to every foot upon which the lead is laid.

DRIPS on FLATS or GUTTERS are formed also as in the preceding manner, and by dressing the joints of the lead as described for rolls. This is used to avoid solder, and keep the work dry.

FLASHINGS are pieces of milled lead, about eight or nine inches wide, and are fixed round the extreme edge of a flat or gutter, in which lead has been used. One edge is dressed over the lead of the flat or gutter, and the other fastened, either by passing it into the joints of brick-work, or by means of wall-hooks.

The PIPES used by the plumber are of various sizes and descriptions. The small sizes are called by their calibre, or bore, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, $1\frac{3}{4}$, and 2, inch pipes. Pipes below $1\frac{1}{2}$ inch calibre are charged by the foot run, and the larger size sometimes by the hundred weight.

*Socket Pipes* are those which are used for conveying superfluous water from roofs, &c., and are called 3, $3\frac{1}{2}$, 4, or 5-inch. They are generally made of milled lead, in lengths of eight or ten feet, dressed on a rounded core of wood, and fastened at the vertical joint with solder. The horizontal joints are formed by an astrigal moulding, in a separate piece of lead, about two or three inches wide, which laps completely over it, both above and below the joint, and hence it is called a *lap-joint*. Two broad pieces of lead, called

*tacks,* are attached to the back lap-joints and spread out, right and left, for fastening the pipes to the wall by means of wall-hooks of iron. The *cistern-head,* which is fixed at the head of rain-water pipes, is either made of sheet-lead or cast in a mould, and is fastened by tacks, as above.

RESERVOIRS are generally formed of wood, or masonry, lined with sheet-lead united with solder.

PUMPS, made by the plumber, may be divided into *Sucking, Lifting,* and *Forcing, Pumps.* The last is now but little used.

The *Sucking-Pump* consists of two pipes, the barrel and suction-pipe, the latter being smaller in diameter. These are joined by flanches, filled with leather, and pierced with holes, to fasten them with screw-bolts. The lower end of the suction-pipe is spread out to facilitate the entry of the water, and it frequently has a grating to keep out filth or gravel. The working barrel is cylindrical, and as evenly bored as is practicable, to give the piston the least possible friction.

The *Piston* is generally made of wood, in the form of a truncated cone, the small end being cut off at the sides, so as to form a kind of an arch, by which it is fastened to the iron-rod or spindle. The two ends of the conical part may be hooped with brass, and the larger end of the cone uniformly surrounded with leather to some distance below its base. This leather band should be sufficiently large to render the piston air-tight, without causing much friction. This is the pump which is generally used for raising water for the common purposes of life.

The *Lifting-Pump* consists, as in the former, of a working-barrel, which is closed at both ends. The piston is solid, and its rod passes through a collar of leather in the plate, which closes the upper end of the working barrel. The barrel communicates laterally with the suction-pipe, and above with the rising main. This pump differs from the preceding only in having two valves, the lower one moveable and the upper one fixed.

The *Forcing Pump* consists of a working-barrel, a suction-pipe, and *serving-main,* or raising-pipe. The last is usually in three parts, the first consisting of one piece, and making part of the working-barrel; the second is joined to it by flanches forming an elbow with it; and the third is the be-

ginning of the main, and is continued to where the water is delivered, where it is furnished with two moveable valves. The perfection of the barrel and piston of this pump is so great, as to require neither wadding nor leather. It is used for forcing water to any great height.

There are two or three other kinds of pumps which require a short description, and they are as follows:—

*Mixed Pumps* are formed by combining the principles of the forcing and sucking-pumps together: when the lower valve of a forcing-pump is above the surface of the water it can raise it only by suction, the manufacture remaining as before. The mechanism of a pump may be employed for converting the weight of water descending in its barrel so as to work another pump.

The *Spiral Pump* is formed by winding a pipe round a cylinder with an horizontal axis, and then connecting one end with a vertical tube, while the other is at liberty to turn round and receive water and air at each revolution. Such a pump is said to be able to raise a hogshead of water in one minute 74 feet high, through a pipe 760 feet long.

The *Water Screw Pump* consists either of a pipe wound spirally round a cylinder; or of one or more spiral excavations, formed by means of spiral projections, from an internal cylinder covered by an external coating, so as to be water-tight. These pumps are used for removing water out of the foundations of bridges, and for supplying pieces of artificial water, as, by means of the Archimedian screw, in the Royal Gardens, at Kew.

The materials of these pumps are manufactured to almost every required purpose, and thus sold to the plumber, who only put them together, so as to make them produce their desired effects.

The different parts of *water-closets* are made in a similar way, and sold to the plumber, who places the basin, apparatus, traps, socket-pipe, cistern, and forcing or lifting pump together, so as to put them into action.

Plumbers charge their sheet lead by the hundred weight, according to prices arranged at intervals by the Warden and Court of Assistants of the Plumbers' Company. Milled lead is two shillings per hundred weight more than the cast-lead.

# CHAPTER XIII.

## HOUSE-PAINTING.

HOUSE-PAINTING is the art of colouring and covering with paint all the several kinds of wood, iron-work, &c. either as an external finish or for protection from the weather. This practice may be divided into four branches; that is to say, COMMON PAINTING, GRAINING, ORNAMENTAL PAINTING, and INSCRIPTION WRITING.

WHITE LEAD, is the principal ingredient used in house-painting; and this is a calx, obtained by rolling sheets of lead into coils, with their surfaces, about half an inch distant from each other, and then placing them vertically in earthen pots, with a portion of good vinegar at the bottom, in such a way that, when set in a moderate heat, the vapour of the vinegar corrodes the lead, so that the external portion will come off in white flakes when the lead is beaten or uncoiled. These flakes, being bleached, ground, and saturated with linseed oil, form the *white lead* of the shops. This composition, if genuine, improves by keeping, and for the best whites it should be, at least, two or three years old. The Nottingham white lead is the most esteemed for what is called *flatting*, or dead-white. This article is so frequently adulterated with common whiting, that it cannot be too carefully examined, before it be used.

LITHARGE is composed of the ashes of lead, and is a kind of dusky powder that first appears in the oxydation of the lead. It is mixed with linseed oil, and used to give the paint a greater capability of drying quickly.

Linseed Oil, which is used in every kind of house-paint, is obtained, by pressure, from the seed of flax, and then filtered to free it from feculæ. This oil should be kept for two or three years, that it may precipitate its colouring particles; as the more transparent it is, the better is the paint, of which it forms a component part. In Holland they whiten linseed oil by the following process, which gives it the effect of age. Having put the linseed oil into a well-glazed pot, they add to it fine sand and water, each of the same quantity as the oil, and having covered the vessel with glass, expose it to the sun, and stir it once every day. This process soon renders it very white; after which it should rest for two days, and is then fit for use.

Drying Oils are usually prepared from litharge, white lead, plaster, and umber, in the following manner: to one pound of linseed oil add half an ounce of each of the above ingredients, and then boil the composition over a gentle fire, taking care to skim it from time to time. When the scum begins to rarify, and becomes red, the fire should be stopped, and the oil left to clarify and settle, when it is fit for use. The scum is called *smudge*, and is used for outside work. Oil, thus prepared, may be bought at colour shops under the name of *boiled oil*, and it is always used for the best house-painting.

Oil of Turpentine, or Turps, is made from the resin of that name, which is obtained from all larch and fir-trees. *Venice Turpentine* is obtained from the larch, by fixing pipes in a hole made in the trunk, and thus conducting the liquid turpentine into buckets. In this state the turpentine has a yellowish limped colour, a strong aromatic smell, and a bitter taste. When this liquid or juice is distilled, by means of a bath, an oil is obtained, which is called *Essence of Turpentine*. The residue of the distillation is the boiled turpentine of commerce. This oil improves much by age, as the older it is the longer will the work performed with it retain its colour. It is much used in what is generally called *flatting*.

All the prismatic colours are occasionally used by the painter, and he varies these, according to circumstances, into almost every gradation of tint. They may be thus classed:—

**Red.**

*Red tending to Orange:*

Vermilion,
Native Cinnabar,
Red-Lead,
Scarlet-Ochre,
Common Indian-Red,
Spanish Brown,
Terra di Sienna, burnt,

*Crimson tending to Purple:*

Carmine,
Lake,
Rose-Pink,
Red-Ochre,
Venetian-Red.

**Green.**

Verdigris,
Crystals of ditto,
Prussian-Green,
Terra Verte,
Sap Green.

**Orange.**

Orange Lake.

**Purple.**

True Indian-Red,
Archil,
Log-Wash.

**Blue.**

Ultramarine,
Ditto, ashes,
Prussian-Blue,
Verditer,
Indigo,
Smalt.

**Brown.**

Brown-Pink,
Bistre,
Brown-Ochre,
Umber,
Cologne Earth,
Asphaltum.

**Yellow.**

King's-Yellow,
Naples ditto,
Yellow-Ochre,
Dutch-Pink,
English ditto,
Light ditto,
Gamboge,
Masticot,
Common Orpiment,
Gall-Stone,
Terra di Sienna.

**White.**

White-Flake,
White-Lead,
Calcined Hartshorn,
Pearl White,
Tray White,
Eggshell White,
Flowers of Bismuth.

**Black.**

Lamp-Black,
Ivory-Black,
Blue-Black.

These colours are nearly all that are employed by the house-painter, and are those which experience has taught him to mix so as produce almost every teint that can be required.

Vermilion is a bright scarlet pigment, formed of common sulphur and quicksilver, prepared for use by a chymical process. It has a delicate body, and will grind as fine as the oil itself, but is too expensive for common use.

Cinnabar is a similar pigment, differing only from vermilion by having a more crimson teint.

Red-Lead, or Minium, is lead calcined till it acquires a proper degree of colour, by exposing it with a large surface to the fire.

Scarlet-Ochre is an earth, with a base of green vitriol, and is separated from the acid of the vitriol by calcination.

Common Indian-Red, is of an hue verging to scarlet, and is imported from the East Indies.

Venetian-Red is a native ochre, rather inclining to scarlet; this is the pigment which is selected for graining of doors, &c., in imitation of mahogany.

Spanish-Brown is a native earth, found in the very state and colour in which it is used.

Terra di Sienna is a native ochre, and is brought from Italy, where it is generally found. It is yellow originally, and in this state is often made use of, and is accordingly placed among the yellow colours. It changes to an orange-red by calcination, though not of a very bright teint, for which property it is sought to produce a pigment of that colour.

Carmine is a bright crimson colour, and formed of the tinging substance of cochineal, with nitric-acid. It is not well calculated to mix up with oil, as its colour changes rapidly by exposure to the air and light.

Lake is a white earthy body, as cuttle fish-bone, or the basis of alum or chalk, tinged with some vegetable dye, such as is obtained from cochineal, or Brasil-wood, taken up by an alkali, and precipitated on the earth by the addition of an acid.

Rose-Pink is a lake, like the former, except that the earth or basis of the

pigment is principally chalk, and the tinging substance extracted from Brasil or Campeachy wood.

Red-Ochre is a native earth; but that which is in common use is coloured red by calcination, being yellow when dug out of the earth, and the same with the *yellow-ochre* commonly used. This latter substance is chiefly brought from Oxfordshire, where it is found in great abundance.

Ultramarine is a preparation of calcined *lapis-lazuli,* which is, when perfect, of a brilliant blue colour; it has an extremely beautiful and transparent effect in oil, and will retain this property with whatever vehicle, or pigment, it may be mixed. It is excessively dear, and is frequently sold at the colour shops in an adulterated state.

Ultramarine Ashes are the residuum, or remains, of the calcined *lapis-lazuli.*

Prussian-Blue is a brilliant pigment; it is the fixed sulphur of animal or vegetable coal, chymically combined with the earth of alum.

Verditer is composed of a mixture of chalk with the precipitated copper, formed by adding the due proportion of chalk to the solution of copper, made by the refiners in precipitating silver from the nitric acid, in the operation called *parting,* in which they have occasion to dissolve it in order to purify it.

Indigo is a tinging matter, extracted from certain plants, which are found in both the Indies, from whence the Indigos of commerce are mostly imported.

Smalt is a species of glass, of a dark blue colour, being coloured with zaffre, or oxyde of cobalt, and afterwards ground to a powder. This beautiful colour carries no body in oil, and can be strewed only upon a ground of white lead.

King's-Yellow is a pure orpiment, or arsenic, coloured with sulphur.

Naples-Yellow is a warm yellow pigment, rather inclining to orange.

Yellow-Ochre is a mineral earth, which is found in many places, but of different degrees of purity. See *Red-Ochre,* above.

Dutch-Pink is a pigment formed of chalk, coloured with the tinging par-

ticles of French berries. It is not well adapted for work in oil, because it fades speedily.

English and Light Pink are merely a lighter and coarser kind of Dutch pink.

Gamboge is a gum brought from the East-Indies; it is dissolved in water to a milky consistence, and is then of a bright yellow colour.

Masticot, as a pigment, is flake-white, or white-lead gently calcined, by which it is changed to a yellow, which varies in teint according to the degree of calcination.

Orpiment is a fossil body, of a yellow colour, composed of arsenic and sulphur, frequently with a mixture of lead, and sometimes of other metals.

Gall-Stone is a concretion of earthy matter, formed in the gall-bladder of beasts: it is but little used.

Verdigris is an oxyde of copper, formed by a vegetable acid: it is used in most kinds of painting where green is required.

Crystals of Verdigris is the salt produced by the solution of copper, or common verdigris, in vinegar.

Prussian-Green is, in composition, similar to blue of the same name.

Terra-Verte is a native earth; it is of a bluish green colour, resembling the teint called sea-green.

Sap-Green is the concreted juice of the buck-thorn berry.

Orange-Lake is the tinging part of anata, or annotto, precipitated together with the earth of alum.

True Indian-Red is a native ochrous earth of a purple colour, but so scarce as seldom to be met with at the shops.

Archil is a purple tincture, prepared from a kind of moss.

Logwood is brought from America, and affords a strong purple tincture.

Brown-Pink is the tinging part of some vegetable, of an orange colour, precipitated upon the earth of alum.

Bistre is a brown transparent colour of yellowish tint.

Brown-Ochre is a warm brown or foul orange colour.

Cologne Earth is a fossil substance of a dark blackish brown colour, a little inclining towards purple.

ASPHALTUM is sometimes employed by the painters to answer the end of brown-pink.

WHITE-FLAKE is a ceruse prepared by the acid of the grape.

TROY-WHITE is simply chalk, neutralized by the addition of water in which alum has been dissolved.

LAMP-BLACK is properly the soot of oil collected as it is formed by burning; but, generally, no other than a soot raised from the resinous and fat parts of fir-trees.

IVORY-BLACK is composed of fragments of ivory or bone, burnt to a black coal, in a crucible or vessel, from which all access of air is excluded, and then ground very fine for use.

BLUE-BLACK is the coal of some kind of wood burnt in a close heat, to which the air can have no access.

Of the COMPOUND COLOURS, *Lead colour* is of indigo and white: *Ash colour*, of white-lead and lamp-black: *Stone colour*, white, with a little stone-ochre: *Buff*, yellow-ochre and white-lead: *Light willow green*, verdigris and white: *Grass green*, verdigris and yellow pink: *Carnation*, lake and white: *Orange colour*, yellow-ochre and red-lead: *Light timber colour*, spruce ochre, white, and a little umber: *Brick colour*, red-lead, with a little white and yellow-ochre.

All the simple colours may be bought at the colour shops, either in a crude or prepared state. They are prepared by saturating them with linseed oil or water, as either is to be used with them, and then grinding them on a slab of porphyry, marble, or granite, till they are perfectly levigated.

All colours are derived from either vegetable or mineral substances; but though the former kinds have a more brilliant effect at first, they soon change when exposed to the atmosphere, which the latter never do.

The painters' tools are few in number, being almost entirely brushes. The *pound brush* is made of hogs' hair, and is used as a duster, till the soft part is worn away. This previous wear adapts it better for spreading the colours for which it is afterwards used. The other brushes vary in size according to the work they are intended for.

COMMON HOUSE-PAINTING may be divided into the following kinds:

CLEARCOLE AND FINISH, which is the cheapest kind of painting; it is performed by first dusting and cleaning what is to be painted, and filling up cracks and defects with putty, called *stopping*.

The whole is then painted over with a preparation of whiting and size to form the ground. Over this a coat of oil-colour, prepared with lead, called the *finish*, is laid. Where work is not very dirty, this may answer pretty well, but not for outside work.

TWICE IN OIL means when the work is twice painted over.

THRICE IN OIL, means when the work has been twice painted over with oil-colours, and once in colours prepared in turpentine.

THREE TIMES AND FLAT means three coats of oil colour and one of turpentine. This is generally used for new work.

BRINGING FORWARD is a term applied to priming and painting new wood added to old work, or old work which has been repaired, so that the whole shall appear alike when finished.

GRAINING is the imitating, by means of painting, various kinds of rare woods; as satin-wood, rose-wood, king-wood, mahogany, &c., and likewise various species of marble. For this kind of work the painter is furnished with several camel's-hair pencils, and with one or more *flat* hogs' hair brushes. An even ground is first laid of a composition formed of ceruse, and the colour required diluted with oil of turpentine. This is then left for a day or two to get fixed and dry. The painter then prepares his pallet-board with small quantities of the colour required; and, being furnished with some boiled oil and oil of turpentine mixed together, tries the effects of the teint by spreading it over a panel, and if it suits, perseveres by doing a panel at a time. The shades and graining is then produced by dipping the flat hog's-hair brushes in the mixture of oil and turpentine, and drawing it down the newly-laid colours. The other particular appearance required is produced by means of the camel's-hair pencil. When all is fixed and dry, the whole is covered with one or two coats of good oil varnish. This kind of painting is not much

dearer than good work in the common way, but it will last ten times as long, by being occasionally re-varnished, without losing any of its freshness.

ORNAMENTAL PAINTING embraces the executing of friezes and the decorative parts of architecture, in chara-obscura, or light and shade, on walls or ceilings. It is performed by first laying a ground of the colour required, then sketching the ornament with a black-lead pencil, and afterwards painting and shading it, so as to give the required effect.

INSCRIPTION WRITING is similar in process to ornamental painting; the painter sketching out the letters in pencil and finishing the outline with colour. If the letters are to be gilt, they are covered with leaf gold, while the paint is wet. After the whole is dry, the superfluous gold is removed with a moist sponge, and the work covered with a coat of good oil varnish.

## VALUATION OF PAINTERS' WORK.

PAINTERS' work, in general, is valued at the yard superficial of nine square feet. Sash-frames are valued at per piece, and sash squares at per dozen. Inscription writing is charged by the inch, *viz.* the height of one letter being taken, and multiplied by the whole number of letters, will give the quantity of inches. Shadowed letters are a halfpenny more than plain ones, and gilt letters treble the price. The charges for painting are regulated in London by intelligent surveyors; but, as colours and oils can be purchased at any degree of purity, painting is often done at twenty per cent. less than the prices so regulated; but the value of painters' work, in all cases, depends upon the quality of the materials and goodness of workmanship, and in reference also to the different species of works.

# CHAPTER XIV.

## GLAZING.

On glass very little has been communicated in the works of the antients. It, indeed, appears, from the ruins of several Grecian buildings, that they had apertures or windows; and it would seem, from the nature of their construction, they were adapted to receive a frame filled with some transparent substance. In some of the apertures discovered at Pompeii and Herculaneum, squares of amber were found; yet, though many of the Roman authors mention glass, it was so rare as to be employed only in the mansions of the opulent.

Bede is the first who mentions glass as applied to glazing windows. He likewise informs us that Abbot Benedict was the first who introduced the art of making glass into this kingdom, about the year 669; and, from the specimens that now remain, it is evident that not only the making of glass, but the art of staining it, made rapid strides towards perfection in a very short time after.

Glazing, as now practised, embraces the cutting of glass, and fixing it into sashes of wood or casements of lead; and likewise the ornamenting of windows with stained glass.

Plain coloured glass may frequently be used with a very pleasing effect, and is very little more expensive than good common glass. Coloured glass is charged by the pound; Claude Lorraine, green, red, &c., at about six or seven shillings, and blues somewhat more.

*Glazing in lead-work* is of the most antient description; sashes being of modern date. These sashes are formed with a groove or rebate, on the back of their cross and vertical bars, for the reception of the glass, which the glazier cuts to its proper size, and beds in the composition called *putty*.

PUTTY is made of pounded whiting, beat up, with linseed oil, into a tough tenacious cement. When used for mahogany frames, a little red-ochre is mixed with it to suit the colour of the wood.

The beauty of glazing depends principally on the colour of the glass. Glaziers now use chiefly what is called *crown glass,* which is divided into three kinds, called *firsts, seconds,* and *thirds,* according to their qualities, on which its value depends. The glass is bought by the crate, which consists of twelve tables of the best, fifteen of the seconds, and eighteen of the thirds. These tables are each about three feet in diameter. A crate of the best glass is valued at about four guineas; of the seconds, about three; and the thirds, two guineas. The crown glass manufactured at Newcastle and its neighbourhood is esteemed the best: the prices of glass are various.

GREEN-GLASS is another sort, much used for common purposes, being not more than half the price of the crown-glass. From many old windows, it appears that this kind of glass was the most antient made use of.

WAVED PLATE-GLASS is very thick and strong, presenting an uneven surface, as if indented all over with wires, so as to leave the intermediate spaces in the form of lozenges; it was formerly much used in counting-houses, &c. to prevent the inconvenience of being overlooked; but though it has lately been superseded by ground-glass, it is still to be obtained in London.

*Ground* or ***Rough Glass*** is used for the same purpose as the above, and is no other than the common crown glass, rendered opaque by having its polish taken off, and rubbing it with sand and water or emery.

PLATE-GLASS is the most beautiful glass made use of, being nearly colourless, and sufficiently thick to admit being polished in the highest degree. The tables of this glass will admit of pieces being taken out of them much larger than can be obtained from any other kind of glass. The British Plate-Glass Company, in Albion-Place, London, is the most celebrated depot

for this species. There it is sold by the inch, in proportion to its size, the value increasing accordingly. Though the expense of this glass, by far exceeds that of any other, yet is now so much preferred, as to be used in many shop-windows in the leading streets.

German Sheet is another species of glass much esteemed, and would be superior to the preceding, had it not a disagreeable appearance, from being very wavy or uneven.

Bohemian Plate-Glass is similar to the above, only possessing a red teint; and though much used about thirty years ago, it is now quite rejected.

Glaziers value their work by feet, inches, and parts, according to the size of the panes, or squares, employed. The charges are regulated by the Masters, Wardens, and Court-Assistants of the Company of Glaziers, and at present run thus:

| | | | | *s.* | *d.* |
|---|---|---|---|---|---|
| Best crown, not exceeding 3 feet, per square | | | | 3 | 10 |
| Ditto, | ditto | 2 ft. 6 in., | ditto | 3 | 4 |
| Ditto, | ditto | 2 ft. | ditto | 3 | 2 |
| Ditto, | under | 2 ft. | ditto | 3 | 0 |

Seconds of the same dimensions are about ten per cent. cheaper; and

Thirds, of similar dimensions, are 10 per cent. cheaper than the seconds.

Green glass is the cheapest, never exceeding eighteen pence per foot.

The price of all kinds of bent glass, for circular and other windows, varies according to the size, the trouble of obtaining it, and fitting it in.

Cottage and some kinds of church windows are glazed in squares, or other figures, in leaden rebates, which are cast and drawn for the purpose, and soldered together at the interstices. This leaden work is of various sizes, according to the strength required, and is used instead of the cross bars of sashes. The grooves left in it for the glass have their cheeks sufficiently soft to be pressed down all round to admit the glass, and again raised up, when the glass has been put in, to keep it firm. Such windows are strengthened by vertical and cross bars of iron, with bands, which, having

been soldered to the lead, are twisted round the iron. In cottage windows the bars, instead of being of iron, are often of wood.

Glaziers formerly cut their glass out with an instrument called a *grozing-iron;* but this process was not only tedious but difficult, and has therefore been entirely superseded by the introduction of the diamond, which is as complete a tool for the purpose as can possibly be required. This instrument consists of a diamond spark, in its natural *unpolished* state, fixed in lead, and fastened to a handle of some hard wood by means of a brass ferrule. The handle is about the size of a moderate drawing pencil. The diamond is the principal working tool of the glazier. His other tools are a rule and several small *straight edges.* The former is divided into thirty-six parts, or inches, and is used for dividing the tables of glass into any required size. The straight edges are merely thin pieces of some hard wood, about two inches wide, and one quarter of an inch thick, and are used for the diamond to work against. Glaziers are likewise furnished with *stopping knives,* which resemble dinner knives, with the blade reduced to about three inches in length, and ground away on each side of its edges to an apex. They are used for bedding the glass in the rebates, and for spreading and smoothing the putty.

*A Hacking-out Tool* is an old broken knife, ground sharp on its edge, and used for removing old putty out of the rebates, which are to be filled with new squares of glass.

The glazier's hammer is similar to the smaller kinds used by other artificers.

Glaziers are also furnished with a pair of compasses, which has one of its legs formed with a socket to receive the handle of the diamond, for drawing and cutting out any peculiar shapes of glass for fan-lights, &c.

Good glazing requires that the glass be cut full into the rebates; for, when too small or too large, it is liable to be broken by the least pressure within, or even the wind from without: moreover, the putty should never project beyond the line of wood in the inside, and large squares should be further secured by small sprigs being driven into the rebates of the sash, and covered over with another coat of putty.

The business of a glazier includes the cleaning of windows, and this forms no inconsiderable portion of the trade in London; some masters keeping one or two men constantly employed therein. The charge is regulated by the number of windows cleaned, and the number of squares in each frame. Windows, exceeding twelve squares, are charged at from 6*d.* to 8*d.* per dozen, the large squares of French sashes being raised about one-third more. The master-glazier takes upon himself the risk of windows being broken by his men, when employed in cleaning them.

In many parts of the United Kingdom it is the custom to measure all the wood-work appertaining to the sashes, for the quantities of glass contained in the respective squares; also, the lead-work. And such is the prejudice in favour of the practice in some places, that if any intelligent person was to attempt to reason them out of it, he would be considered a most inequitable valuator, and unworthy of being countenanced. Time and concurring circumstances, it is presumed, may, at some period or other, equalize our customs, weights, and measures; but until that period arrives, the system of valuation must be dependent upon local customs. The net quantities of glass should, in all cases, be measured, except in circular fan-lights and similar works, where the glass should be measured in the widest part; and because the pieces cut off to make the glass fit the apertures can be considered only as waste glass, the price or allowance for which is not embraced in the value charged by the glazier for his glass so consumed.

# CHAPTER XV.

## OF BUILDING IN GENERAL.

Having already treated on the component parts of Building, under the respective heads of Carpentry, Masonry, Bricklaying, &c., we shall now attempt to give a general view of the subject; and, that the reader may be enabled to follow us, in fully comprehending our description, we shall explain, methodically, those technical terms, used by architects and builders, which require to be previously understood; and then present the various parts of a building, in their natural order, with such remarks as may be practically useful.

To those who, by practice and experience, are already acquainted with the subject, such an arrangement and explanation cannot but be agreeable; and to those who do not possess such advantage, this mode of proceeding will be found materially useful, as it will imperceptibly and effectually conduct them to an acquaintance with the most prominent features of the art.

The student is presumed, of course, to be acquainted with the geometrical parts of this work; and, more particularly, all the *definitions* of *superfices* and *solids*. This information is indispensable, as the parts of a building are either the simple forms of some one geometrical solid, or compounded of portions of several: and, although the forms of objects are most easily understood by a reference to such as we have been accustomed to see, yet, as the same forms are not known to all classes of men under the same names, the language of geometry is the only language which can be employed to convey ideas of magnitude, form, and position.

In speaking of *Length* and *Breadth*, as applied to any object fixed to the horizon, as a building, we mean such dimensions as are measured in an horizontal plane. *Depth* is the distance which some part recedes from a surface, without regard to the position of that surface. *Height* is estimated in a vertical line; that is, in a line perpendicular to the horizon.

Rooms are the interior vacuities or habitable parts of a building. They must be closed on all sides for security, lodging, and comfort, and for all manner of purposes to which they may be applied. For the convenience of entering rooms, or of passing from one room to another, apertures should be made on one or more sides, which may be closed at pleasure, by means of moveable parts known by the name of *doors*.

Rooms are disposed one above another, or by the side of each other, as may be found convenient. One side of every room must be an horizontal plane, for the convenience of walking upon, and for placing various articles of furniture in the most secure position; this side is denominated the *floor*. When several rooms are placed side by side of each other, the *passages* or communications will be most conveniently effected when all the floors are on the same level.

Again, for the convenience of the inhabitants, and to add to the strength of the building, not only the exterior, but likewise every side, of a room which appertains to the floor, should be carried to a certain height from it, in a line perpendicular to the horizon. Hence, it is clear the floor must be in a straight line, and the side thus carried up must be a plane surface.

The solid parts contained between the vertical surfaces are the *walls*. The remaining sides, opposed to the floor, are denominated the *ceilings*. The latter parts may have such forms which the materials employed in the construction will admit of. The forms of many parts of buildings are altogether arbitrary, as to their use; they are, therefore, determined by the ideas of economy or beauty; upon such principles as these the formation of ceilings are regulated. If economy be the chief object, the ceiling is a plane surface as well as the floor; and hence, when several rooms are placed one over the other, with plane ceilings, the surfaces of the solid, contained between the floor and the ceiling of the room below, are parallel planes.

Keeping the same object in view, the surface of walls will not only be planes, but they will also be parallel to each other, and equally thick throughout. The forms of walls are determined by the line upon which they rise from the ground: thus, if the line be straight, the wall is called a *straight wall;* or, if it be circular, the wall is said to be *circular,* and so on.

Straight walls are generally built; circular walls occasionally; but those of other forms are elliptic, &c., but they seldom occur in the common practice of building, at least in exterior walls.

A wall which divides one apartment from another, is called a *partition* or *division wall.*

When two walls form an external or internal angle, the line of concourse made by the two sides is termed an external or internal *quoin,* or an external or internal angle.

To combine strength and stability with economy in an edifice, the walls, as they rise, should diminish in thickness; keeping in view that a straight line, ascending from any point of one of the surfaces, ought not to fall without that surface. If the line thus ascending fall entirely within the solid mass, the face of the wall is said to *batter;* and the horizontal distance between the vertical line, ascending from any point in the line terminating the upper extremity of that surface, and the line terminating the lower extremity of the same, is called the *battering of the wall.* The exterior surfaces of walls are generally executed in planes perpendicular to the horizon. When the face of a wall is not one entire or continued surface, or when it is formed by two or more continued surfaces, each rising from the horizontal base which forms the top part of the wall below; the part thus connecting the two surfaces is called an *off-set.*

When a house consists of several apartments one above another, each apartment, or as many as may be on one floor, is called a *story;* and when each story of a house has a number of apartments, the aggregate of the apartments on each story is called a *suite of apartments,* that is, when the rooms are connected by folding or other sorts of doors.

When a building consists of two or more stories, it is usual to diminish the walls from the inside faces, by breaking each side into several surfaces, so

that the off-sets may be immediately under the ceilings; the sets-off thus made will not only prevent them from being seen, but will also afford a secure support to the floors. Hence, also, the floors, extending from one side of the building to the opposite side, will tie the walls firmly together, and prevent them either from spreading or approaching towards each other.

The exterior walls of a building are not only connected by the floors, but likewise by the division or partition walls.

The distance between the two nearest surfaces of parallel and opposite walls is called the *span*, or between external walls, the *span of the building*.

The exterior parts of a house, by which its upper extremities terminate and extend over the area of each of its floors, in order to protect and secure the interior, is denominated the *roof*.

The forms of roofs are various, and depend upon the nature of the climate, and prevailing custom of the country. Flat roofs were mostly used by the antients; but the Greeks, from their country being at times exposed to heavy rains, soon perceived the inconvenience of flat or horizontal roofs. They accordingly constructed their roofs in two inclined rectangular planes, sloping from the middle towards the sides, and inclining equally to the horizon, so as to terminate each wall in an isosceles triangle with an horizontal base. The proportion of the height of this triangle to its base was in the ratio of one to eight, or one to nine; or, speaking technically, the height was one-eighth, or one-ninth, part of the span.

The Romans, who had still more occasion than the Greeks to provide for the speedy discharge of rain from their houses, did not alter the Grecian form of the roof, but varied its proportion, making the height of their roofs form one-fifth to two-ninths of the span. After the decline of the Roman Empire, high-pitched roofs were very generally introduced; the standard form being that of an equilateral triangle. No part of the practice of building has been more the object of caprice than the proportions of the roof. Even in the present day, we meet with almost every variety of proportion which can subsist between the height of the roof and its span. In ordinary dwellings the height varies from one-third to one-fourth part of the span; in other

cases, the proportion depends upon the taste of the architect and the style of the building.

Roofs that are high-pitched discharge rain and snow more quickly than those which are lower; they are less liable to be stripped of their covering by the wind, and the rain is not so easily blown through their joints; but they are more expensive than low roofs, as they require longer timbers, and a greater quantity of covering. But, though low roofs possess the advantage in point of economy, they require large slates and greater care in the execution.

Apertures built in walls for the admission of light are called *windows*. Those for egress and regress are termed *door-ways*. The framed-work for closing the aperture is called *the door*. The surfaces which surround the aperture, and which are contained within the two surfaces of the wall, are called the *sides of the aperture*. The lowest side of every aperture is termed the *sill*, and is always parallel to the horizon; the two sides which spring upwards from the sill are called the *jambs*, and these should be perpendicular to the horizon, and of an equal height. The remaining side, opposed to the sill, and which connects the tops of the jambs, is termed the *soffit*. The *soffit* is generally a plane surface, consisting of parallel planes; and since each jamb rises to the same height, the soffit will, in this case, be parallel to the horizon. Occasionally, however, the section of the soffit, parallel to the surface of the wall, is some part of a circle, not exceeding the semi-circumference. The points from which the section rises from the tops of the jambs are called the *springing-points*. The solid contained in the soffit and the vertical surface of the wall is denominated an *arch;* in this case, the soffit is termed *the intrados of the arch*. If the section of the soffit be less than a semi-circle, the arch is called a *scheme-arch;* but if a semi-circle, it is termed a *semi-circular arch*. In some cases, the jambs do not ascend perpendicularly to the horizon, but stand at equal angles therewith, so as to approach nearer towards each other at the summit than at the bottom: and examples of this sort are not unfrequent in antient and modern works.

The sections of apertures, parallel to the face of the wall, are sometimes entire circles, or entire ellipses, having one axis parallel to the horizon; and,

consequently, the other perpendicular thereto: in this case, the aperture cannot properly be said to have sills, jambs, or soffits. Occasionally, the section of the soffit, parallel to the surface of the wall, is constructed of two equal and similar concave curves, meeting each other in a receding angle, and in a vertical line which divides the aperture into equal and similar parts, so that the whole opening may form a symmetrical figure: arches of this description are termed *Gothic arches.*

Semi-circular-headed windows have a pleasing effect in circular walls, particularly when the exterior surface is an entire cylinder, and the diameter of considerable magnitude; but, in a small building, they greatly weaken the construction of the walls, and produce a disagreeable effect by the overhanging of the head.

Since apertures for the admission of light are indispensable, it is essential, as well for the strength as for the beauty of the edifice, that the sills of all the windows in the same story should be in the same straight line; and, also, that each jamb of a window in any story should be in a straight line with the jamb of a window in every other story.

The solid parts of walls between apertures are termed *piers,* as also the external parts annexed to such apertures, which are identified as external piers, or *quoins,* commonly so called.

When any uninterrupted part of the exterior walls of a building contains more than two equal and similar windows on one level, the beauty of their arrangement will require that the intermediate piers be equal in breadth; for the same reason, the extreme piers in any apartment, which has one or more such windows, ought to be equal to each other. In all cases, where fanciful dispositions of the apertures are attempted, they ought to be disposed in symmetrical order.

Windows, in modern rooms, in which they are introduced to light the apartments, are, by means of jambs standing obliquely to the faces of the walls, made widest within; and these obliquities are called the *splays* or *splayings of the jambs,* or more simply the *splays:* and in these cases the windows, or jambs, are said to be *splayed.*

Each jamb of a window will generally consist of four vertical planes within the two surfaces of the wall. The first plane from the exterior surface of the wall forms an external right angle with that surface; the first and second planes make with one another an external right angle; the second and third, an internal right angle; and the third and fourth, an obtuse angle. The fourth plane is generally continued down to the floor, in order to form the side of the recess made from the inside of the wall below the sill of the window; so that two of the three sides of this recess are formed by the continuation of the two planes of the jambs next to the inner surface of the wall, and the third face is a surface parallel to that surface joining the continuation of the line of concourse at the meeting of the planes which form the obtuse angle in each jamb.

The most usual form of a room is that of a rectangular prism; and, consequently, it consists of four vertical sides, and of two sides parallel to the horizon.

In large edifices, for the sake of beauty and variety, the forms of apartments, as they rise from the floor, are sometimes made circular or elliptic; and sometimes, they are compounded of a rectangular portion in the middle, and of symmetrical circular segments at the ends, having the chord or diameter extending either the whole breadth of the end to which it is attached, or only to a part of such breadth, leaving an equal portion of it at each extremity of the chord. In this case the faces of the walls consist of two opposite rectangles, and the ends of equal portions of a cylindric surface.

When the floor of a room is rectangular, the ceiling is usually of the same form. In magnificent apartments, however, ceilings are often made to rise from each side to the middle in a concave shape, presenting the surface of a cylinder, having its axis parallel to the horizon. The chord of the cylindric section is extended to the breadth of the room; so that, in every section parallel to one of the ends of the apartment, the upper part of that section will be an equal segment of a circle.

Ceilings, formed simply of cylindric surfaces, are termed, by mechanics, *waggon-heads,* in imitation of the coverings to broad-wheeled carriages; but

the proper term for soffits to rooms, whether to halls, churches, chapels, or domestic apartments, is *coved ceilings*, which are of various forms.

The cylindric or coved ceiling is not the only form which a rectangular apartment will admit of. It may also consist of a quadrantal portion of a cylindric surface, rising from each vertical face to a level oblong in the middle; and this compound form, also, is termed a *coved ceiling*. The multifarious dispositions of which are infinite.

And without altering the figure of the floor, the ceiling may be formed of cross arches; that is, such that each arch may coincide with the surface of a cylinder, having its axis parallel to the horizon, and to the sides of the apartment. When the summits of each arch rise to the same height, this kind of ceiling is called a *groin*, or is said to be *groined ceiling*.

The rectangular floor will also allow of a concave ceiling in an ellipsoidal or spherical form, with one of its axis' in the line of intersection of the two diagonal planes, which may be conceived to pass through each of the four lines terminating the vertical sides, two by two. In this case, the planes which form the four vertical sides of the room, will not meet the ellipsoidal or spherical surface in a straight line, but in a curve of an elliptic form, or in a circular segment rising from each corner to the middle of each vertical adjacent face.

As the circles or arcs, which form the lines of demarcation between the ceiling and the vertical faces of the apartment, descend from the middle of each upright face to the vertical line, formed at the angle, by those faces, the ceiling is termed a *pendulous ceiling;* or it is denominated a *pendentive* one, being suspended in the manner described.

The floor of an apartment may have any geometrical figure that the fancy of the architect may suggest. A building occupying the site of an equilateral triangle, or of a regular hexagon, will divide without any loss of space into apartments, having also their floors in the forms of equilateral triangles or hexagons, and doors may be inserted in the middle of the side of one apartment without destroying the symmetry of the adjacent room; yet none of those figures are so convenient as the square or rectangle: however, they are

sometimes employed for the sake of variety, where motives of economy do not restrain the expense.

When the form of an apartment is spoken of, we mean that of the floor; since all the horizontal sections below the ceiling are equal and similar figures.

Forms of all manner of rooms, besides the square, or such as are rectangular, are denominated *fanciful,* or fancy rooms, which may be made very beautiful.

The floors of apartments are, however, seldom regulated by the forms of the buildings. But, as the sites of edifices are generally rectangular, apartments constructed in the forms of polygons occasion not only great waste of space, but also of materials; and such forms likewise require to be fitted with more than ordinary attention to elegance; hence, when employed, no restraint should be laid as to expenses. It, however, rarely occurs that a suite or series of rooms have more than one polygonal apartment, unless it may be in corresponding parts, in order to render the whole disposition symmetrical.

Apartments having others immediately above them, and on every side, cannot be sufficiently lighted. Hence it would be improper to build a house of a rectangular form, and of two or more stories, with more than two apartments in breadth. If, therefore, it is desirable to build upon a large scale, the fronts of the edifice, on all sides, must be extended, or the middle of the area be left open without any building, or certain parts must be left entirely uncovered, or at least with sufficient exposed apertures, to be filled with glass for the admission of light.

As it is desirable to render every apartment conveniently accessible, without passing through any other, a certain portion of every building should be taken for this purpose; and the parts thus occupied, when not very wide, are termed *passages.*

Passages of communication may be lighted in various ways. If there be only one series of rooms in the breadth, their situation must then be on the sides of the building, and consequently they may be lighted by apertures in the exterior walls, to any degree that may be desired: but if the whole, or any part, of the building has two rooms in breadth, and more than two in length,

the situation of the passage must be naturally in the middle, with one room in depth on each side of them.

If the rooms are not very numerous, the passage may be lighted from one of the ends, but when the length is considerable, it ought to be lighted from both: but, when the edifice is very long, cross passages should extend to the sides; and these will afford the most convenient and private entries to the rooms on each side of them.

The apartment for the stairs must have apertures through all the floors, or be entirely open to the top, except the solid parts for walking upon, in order to give the occupants sufficient light. The flat parts on the same level with the floor are called *landings*, and these afford passages into the surrounding rooms. This mode of approaching them is adopted in all descriptions of edifices; but, in small buildings, it is the only way of entering the rooms, particularly in the upper stories.

When the apertures for the stairs are surrounded on all sides with rooms, the passages are usually made entirely round the stairs, with apertures in the walls of enclosure, in order to light the adjacent passages.

In large buildings, the number of stair-cases should be proportioned to the magnitude of the edifices; and the former should be regulated so as to require the fewest passages, and by these means due portions of the occupants may be kept desirably separate from each other; but with such means of communication as to be accessible to certain individuals of the house, at the will of the proprietor.

In the uppermost stories of buildings, passages may be introduced almost in any direction which may give the most convenient access to the apartments, as light, it is presumed, in most of such cases, may be easily supplied from apertures left in the ceilings or adjacent roofs.

In some magnificent edifices, the rooms in the several heights are so constructed that each story may be connected by one lofty apartment, that is, by means of large apertures in each floor; and, in this manner, the rooms of the surrounding buildings may be accessible, that is, by means of the residual parts of the floors on the sides of the apertures adverted to.

As it is necessary for the comfort of the inhabitants that rooms should be

kept of proper temperature at certain seasons of the year, fires must be introduced, for the purpose of communicating warmth to them. To effect this in the most convenient manner, certain recesses, commonly of a rectangular form, are made in the walls on the sides of the rooms; and these serve as receptacles for fuel; and, to take away the smoke, tubes, or flues, are carried up from these recesses, in the thickness of the wall, to the summit of the building. The openings from the sides of the rooms are called the *fire-places*; and the tubes, or flues, for carrying off the smoke are denominated the *funnels*, or *flues*. The solid parts of the walls, between the funnel, or flues, and the rooms, are called the *breasts of the chimnies*. As the forms of the apertures for the fire-places are generally rectangular, the vertical sides are called *jambs;* and the sides which stretch over the tops of the jambs, parallel to the horizon, are called the *mantles*. The portions of walls, containing the terminations of the chimnies, which are always carried above the roofs, are called the *chimney-shafts*. When walls contain a great number of flues, they are called *stacks of chimnies:* and, if the funnels, or flues, approach very near to each other, the solids which divide them are termed *withs*.

To prevent chimnies from smoking, they ought to be so constructed that the current of air which naturally presses towards the fire-places, may not proceed entirely through the fires, but in such manner that portions of the air may pass immediately over the flame, so as to force the smoke up the chimnies; for as the air is heated it becomes more volatile and desirous of ascension.

With regard to the construction of the funnels, or flues, sharp angular turns must be avoided, as they retard the ascent of the smoke. The form of the chimney is not always the cause of apartments being annoyed by smoke; it has been proved, beyond doubt, that much depends upon the situation of the building, as similar forms, in different situations, will often have different effects. Consequently, in building chimnies, no effectual precaution can be taken, nor can any remedy be applied until the fires are made. Without the agency of contrary currents of air, smoke may be occasioned from the mere form of the chimney; for if the flues are too narrow at the top, the smoke will not be discharged so quickly as it is generated; and in time, therefore, it

must fill the passage or flue, and ultimately the apartment itself. To provide, as much as possible, against smoke, in the building of chimnies, the apertures should be carried up in gentle windings or curvatures, particularly near the top, as all angles and sharp turnings are obstacles. For the same reason the interior surfaces should not be left rough, but should be smoothed over with plaster; and all pieces of lime, shivers of stone, or broken brick, left by the carelessness of workmen, should be removed, as the wall is carried up. On this account, too, circular flues permit the smoke to pass more freely than those which have rectangular sections; and, therefore, if expenses are not primary considerations, they should be so constructed that their surfaces may be those of hollow cylinders. If these precautions are found insufficient, the narrowing of the apertures above the fires should be tried; but as these remedies are sometimes inconvenient, they ought, perhaps, to be the last of the chimney-doctors' resources.

The doctrine of smokey fire-places is as yet very imperfect; many experiments have been tried, but still we have not obtained any general and satisfactory results, notwithstanding the celebrity of those who have made them. The writings of Dr. Franklin, Count Rumford, and Mr. Clavering, contain details of experiments on smokey chimnies, and the works of those authors may be consulted by such as wish to enter more fully into the subject.

The superficial surfaces for walking upon we have hitherto called the *floors;* but this term, more properly speaking, is applicable to the thicknesses of timber or stone floors. So that, when apartments are placed over each other, the solid parts contained between the ceilings of the lower and upper apartments, and the surfaces for walking upon in those above, are called the *floors.*

Floors constructed of stone are more particularly denominated *pavements.* The surfaces upon which we walk may, therefore, with propriety, be called the *levels of the floors or pavements.*

Walls underneath windows are generally recessed from the bottoms of the windows to the levels of the floors; and these increase the areas of the floors. Each vertical side in the same plane with the vertical side or jamb of the window is termed the *side* or *elbow of the recess;* and that surface of the recess which is parallel to each face of the wall, is denominated the *back.*

## PROPORTIONS OF THE APERTURES OF DOORS AND WINDOWS.

Door-cases were formerly constructed of trapezoidal forms, that is, wider below than above; this probably arose from such doors possessing the inherent power of shutting without the aid of the passengers. Instances of these forms are not common, but may be seen in the Bank of England, and several other modern structures, where the doors are hung upon such scientific principles as not to require any trouble in shutting.

The dimensions of the apertures of doors should be regulated by the magnitude of the buildings. All the doors in the same stories are generally made to correspond to each other in heights. In private houses they may extend from three to four feet in widths, and from seven to eight feet in heights, or more, in proportions to the heights of the stories. When doors exceed three feet in width they should be closed with folding leaves, in order that the rooms which they separate may be occasionally united: this practice is prevalent, and found very convenient for the reception of company.

When the front of a building has only one door, it is generally placed in the middle, not only to preserve the symmetry of the front, but also to shorten the access to the various apartments. But in town houses this disposition is not convenient, since most dwellings have only one apartment in the extent of the front, consequently the external doors are, in most cases, if not always, at one end.

With regard to windows, the heights of the sills were formerly from three to three feet and a half high from the floors, which was convenient for leaning upon; but of late years, in imitation of the French, it has become the fashion to make the sills of the windows equal with the levels of the floors, particularly in the principal stories; and in each of the others, the heights of the sills are now reduced to two, or two feet six inches, or thereabouts.

In regulating the dimensions of windows, it may not be superfluous to remind the proprietor, or builder, that, although it may be very pleasant in summer to have the apertures for the windows either very large or very numerous, yet the extraordinary area occupied by them will render the apartments very cold in winter; and to provide against these inconveniences, double glass frames are sometimes deemed indispensably necessary. In France, and in Italy, where the climate is warm, such windows are admissable; but, in the streets of London, we are at a loss to present any apology for their introduction: they seem to be of little use, except to inhale the muddy exhalations of dirty streets. Verandas are equally absurd, which are also to be observed on the northern sides of our streets and squares, which the rays of the sun seldom or ever visit.

## PROPORTIONS OF APARTMENTS.

The proportions of apartments depend very much upon the use to which they are intended to be applied. The lengths of dwelling-rooms may extend from one to one and a half, or to twice their breadths; and in galleries even four times. In general, however, it is to be observed, that the greater the capacities are, the more the lengths may exceed the breadths. Thus, in small houses, the dining and drawing rooms may be square; but, in larger edifices, they may extend even to be a double square. With regard to the heights, three-fourths of the breadths are esteemed good proportions to the other dimensions. When the ceilings are coved or arched, the heights may be equal to the breadths, or to one and one-quarter the breadths. The breadths of the principal passages may be one-third of those of the principal rooms; and the breadths of passages, or of passages belonging to a common house, may be one-fourth of the breadths of the principal rooms: the heights of passages should be the same as those of the rooms, but the lengths must be regulated by the buildings.

When the heights of rooms exceed the proportions adapted to the other dimensions, cylindrical vaultings, coves, domes, groins, &c., may be introduced, as may be best suited to the use made of the apartments.

The heights of ceilings are necessarily regulated by those of the principal rooms of a story; hence, apartments of an inferior description will often have their ceilings disproportionately high. To remedy this, floors may be introduced so as to divide the heights into two stories; the lower one of a height proportioned to the length and breadth of the room, and an upper one sufficiently high to admit of persons walking erect. In this case, the upper story is termed a *mezzanine* or *intersole.*

Mezzanines, when they can be introduced, are exceedingly convenient for servants, lodging-rooms, powdering-rooms, wardrobes, &c.

In buildings where beauty and magnificence are studied rather than economy, the halls and galleries may be raised to the height of two stories. Saloons are frequently raised the whole height of the building, and have galleries at the height of the stories around the interior circumference, for the purpose of communication with the various apartments.

A *Stair,* or set of steps, is a structure by which persons may ascend to, or descend from, any story with ease and pleasure.

The surfaces upon which our feet are set, in the act of passing up or down, are called *treads;* these should be equi-distant horizontal planes, placed at convenient distances.

But when two treads are joined together by a third plane, rising perpendicularly from the plane of the treads, so as to have the breadths of the lower treads on the front, and the breadths of the upper treads on the back of these new planes, the third series of planes thus introduced are called *risers.*

Every riser and tread forming an external right-angle is called a *step.*

The line of concourse formed by the meeting of the riser and tread of a step, is called the *nosing.*

Sometimes the tread of a step projects, in a small degree, beyond the riser below it, and is rounded so as to make it at once strong, and agreeable to the eye; this termination is also termed the *nosing* of the step.

Steps may be supported at each end by walls, and this is very frequently done in common houses.

A series of steps, having all the treads equal, is called a *flight of steps*.

It is easy to conceive that a stair, consisting of one flight, must be very inconvenient, on account of the great length of the area which would be required to contain it. It will be proper, therefore, to show in what manner the direction of the ascent may be changed, in order to prevent the length from exceeding the dimensions of the rooms adjacent.

And this difficulty may be overcome by allowing a double area for the stair, with a floor between them, extending from the entrance where the stair begins to such a distance as will leave sufficient breadth for the passenger to pass from one stair-apartment to the other. Now it only remains to construct two equal flights, each half the height of the story; the first being placed on a proper floor, and made easy of access; and having a surface for walking upon, on a level with the top of the highest riser, and extending over the whole breadth of the two stair-apartments. The next flight may be raised upon this floor, and may have a similar floor at the top with its surface on a level with the floors of those apartments in the story to which a communication is required.

The floor between the two flights is termed a *half space* or *resting place;* and that upon a level with the floor of the story, at the head of the second flight, is denominated a *landing*.

And here the landing naturally points out the situation of the door or doors.

In this manner we may ascend to the uppermost stories of buildings, or to as many stories in them as are deemed requisite.

The two apartments, or *areas*, each containing flights of steps, are collectively termed the *stair-case*.

The wall which divides the two flights is called the *newel* of the staircase. As walls surrounding the stair are commonly carried up in the form of rectangular prisms, by way of rendering the turning easy to the passenger, the angles of the newels are generally reduced by forming them into semi-cylinders.

When the apartment, or arena, allowed for the stair-case, require the steps to be inconveniently high, instead of the half-space, steps are introduced, with their treads diminishing in breadths towards the newel.

The diminished steps, thus introduced, are denominated *winders;* and by their means the stair is made to consist of two equal flights, with a series of winders between them.

When the thickness of the newel, or wall between the flights, is very considerable, another flight of steps is sometimes inserted between the planes or faces of the newel, extended into the passage of the stair, round which the person ascending has to turn, in order to proceed to the upper flights. By this introduction, the stair is made to consist of three flights, and two level parts, called *quarter-spaces,* between each of the two flights.

These quarter-spaces are also occasionally occupied with winders, by which means an easier ascent is gained, and the want of room compensated for as much as possible.

From what has been said, it may be easily conceived that floors of stairs may have many different forms, and that the steps may always be properly adapted to those forms, with convenient quarter-spaces, half-spaces, and landings, where required.

The apartment, or *arena,* for the stairs being a prismatic cavity, the form of the stair-case is denominated from the area contained within its walls, at the base or floor from which the adjacent walls rise.

Therefore, if the floor underneath is rectangular, quadrangular, circular, or elliptical, the stair-case must also be rectangular, quadrangular, circular, elliptical, or as the case may happen.

Now let us conceive the newel to be disengaged from the ends of the steps, so as to form a complete prism, and to be taken out from the level of the floor, and the steps to remain firm; the stair thus constructed is a *geometrical stair.*

The open space left by the newel is called the *well-hole.*

The continuation of the ends of the steps next to the well-hole is denominated the *string.*

The surface of the stair, opposed to the floor or to the steps, as seen from below, by those ascending, is termed the *soffit.*

The newels of stair-cases are sometimes constructed hollow, with apertures through the sides.

Examples of this kind may be seen in St. Paul's Cathedral, where the stairs are cylindric, or stand upon circular bases; the examination of which will afford great satisfaction to those who derive pleasure from scientific research.

The grandest example of a geometrical stair-case, upon a circular base, may be seen in St. Paul's, which cannot fail to attract the attention of the mathematician, geometrician, and architect.

A stair-case having a newel in the middle, is called a *pillared* or *newelled stair.*

A stair contained within a circular or elliptical wall is called a *winding stair;* or one which is circular or elliptical, as the case may be.

Geometrical stairs are much more elegant than *pillared* stairs; and those that have rectangular bases, when constructed without winders, are deemed handsomer than geometrical stairs which rise from a circular or elliptic base; unless, indeed, the diameter be very large, as in the case adverted to, in the sublime structure of St. Paul's.

In ordinary houses the breadths of the steps are generally from 10 to 12 inches, the heights from 6 to $7\frac{1}{2}$ inches, and the lengths from 2 feet 6 inches to 4 feet. In more stately mansions the steps may be from 4 to 6 inches high, from 12 to 15 inches broad, and 6 feet long and upwards, in proportions thereto.

Any portion of the exterior side of a building which protrudes itself towards the spectator, is denominated a *projection* or *break;* and a part that recedes from him, is termed a *recess.*

When deep semi-circular recesses are made for ornament, they are termed *niches,* for the reception of busts or statues.

To prevent the disagreeable sameness that would arise from the view of the plain and regular surfaces of walls and ceilings, certain ornaments are introduced, which compose or divide the surfaces.

When these dividing parts are formed of curved surfaces and planes, so as to meet in edges, forming straight lines parallel to each other, and to the sur-

faces which they compart; and, at the same time, the curved parts are portions of cylinders or cylindroids; the surfaces thus formed are termed *mouldings.*

If these mouldings be conceived to be bent round a cylinder or cylindroid, or round a building in either of these forms, so that the edges of the mouldings may be in planes perpendicular to the axis of the cylindric or cylindroidic surface, they are called circular or elliptic mouldings.

In ordinary cases of modern building, the general position of mouldings upon the walls of edifices, either within or without, are horizontal.

When mouldings are applied to a wall, for the purpose of dividing its surface, the entire should be so constructed that the parts shall not hide each other, unless with the intention to produce a shade.

Every separate part is termed a *member*. Hence, in the same collection of mouldings, those members which are most remote from the horizontal plane, passing through the eye, must be the most remote from the surface of the wall, in order to be seen to the best advantage.

In speaking of the *section of a moulding,* we mean the surface which would arise from cutting it by a plane, perpendicular to one of its edges.

All edges formed by the angular meeting of any two surfaces, are called *arrises,* when they terminate external angles.

The plane surfaces, which enter into the combination of mouldings, are generally either parallel or perpendicular to the horizon. When this is not the case, the deviations from this position will be noticed.

In any curved moulding, terminated by two edges, or arrises, that edge which is the most remote from the eye is also most remote from the surface of the wall; except in mouldings of a cylindric form, which, in general, must be very small when above the eye, as otherwise they will conceal those which are above them. When cylindric mouldings are situated below the eye, semi-cylindric forms are occasionally introduced: these are made so large as to constitute the principal features of the combination, because mouldings in these depressed situations are never so far removed from the eye as to be out of the reach of near inspection.

Hence, to produce the best effect, the situation of mouldings above the eye, the manner in which they are illumined, and even the forms themselves, will differ from the situation, form, &c. of those mouldings which are below the horizontal plane passing through the eye.

Small mouldings of a semi-circular section are called *Beads;* and these are sometimes introduced in a combination of mouldings above the eye, but much oftener below it.

A large semi-circular moulding is termed a *Torus;* its situation is naturally below the eye.

When the form, or section, of a moulding is concave, it is called a *Cavetto;* but below the eye may be either a *Scotia* or *Cavetto,* according as the curvature varies from both its extremes. A convex moulding above the eye is denominated an *Ovolo.* A moulding which has one part concave and another convex, or that which has its section composed of two curves of contrary curvature, is called a *Cymatium,* a term which literally signifies a *wave.* When the concave part of a cymatium is more distant from the horizontal plane of the eye than the convex part, it is called a *Cyma-recta;* but if the contrary be the case, it is styled a *Cyma-reversa.*

It may be proper to recall to the student's recollection, that, in every moulding above the eye, the upper edge recedes farther from the face of the wall than the lower edge.

*Curved Mouldings* are always separated from each other by a small member, called a *Fillet.* This member consists of two plane visible surfaces, one perpendicular, and the other parallel, to the horizon.

If one of the intermediate members of a collection of mouldings above the eye consist of a lofty vertical plane, with a considerable projection underneath, either a level or inclined plane, it is called a *Corona, Larmer,* or *Drip.* The use of this member is to throw the water from the lower edge of the vertical surface, without changing its course to that underneath, to protect the lower parts.

Mouldings, which may be generated by planes carried round their axis' in those planes, are called *rotative mouldings.*

Where buildings have a series of mouldings at or near their tops, such series are termed *Cornices.*

Mouldings below the plane passing through the eye, or at the bottom of a building, is called the *Base;* and here we may observe, that the part of the building under the base protrudes beyond the surface of the wall above the base.

Any intermediate collection of mouldings is denominated a *moulded string course.*

A series of mouldings, placed over the top of each vertical side of a room, is termed a *Cornice;* but when the series is situated near the bottom of the room, it is styled a *Base.*

A series of mouldings placed at the springing of an arch, or where each end begins to rise from the vertical surface, is called an *Impost.*

A series of mouldings round a cylindrical arch, having their edges circular, and these edges described from a certain point in the axis of the cylinder, is called an *Archivault.* Or, if the arch be elliptic, with a series of mouldings around it, and if the mouldings have their edges equi-distant from each other, and from the wall, such a collection is also called an *Archivault.*

The surface of a wall is technically denominated the *Naked of the wall.*

A surface, parallel to the surface of a wall, and enclosed on all sides by mouldings, is called a *Panel.*

By means of bases, strings, cornices, panels, &c. we may easily conceive that a wall is susceptible of being comparted into very elegant symmetrical forms.

When the face of a wall is decorated with mouldings, bordering on the margin of an aperture, for a door or window, such disposition of moulding is called an *Architrave.*

Mouldings, or solid parts, which protrude towards the spectator, are called by the general name of *projections;* and whatever distance any part is from the wall, that distance is termed the *projection* of that part.

A *Tablet* is a projection fixed in a wall, with one face parallel to the surface; and the sides of the tablet, which connects its face with the surface of

the wall, are generally planes perpendicular to that surface. The forms of tablets, though occasionally circular, are generally rectangular. However, they are susceptible of every regular geometrical figure, or combination of figures, symmetrically disposed; that is, so that the parts on the right and left correspond, which should be the case, not only with the subordinate, but also with the several component parts of architectural decorations.

A series of mouldings is said to *return*, when a vertical section of them, parallel to the face of the wall, produces the same forms as a vertical section perpendicular to that face.

When return mouldings do not reach the extent of the wall, or when they extend to a very small distance only, they are said to *profile*, or *terminate, upon the wall;* that is to say, the form or impression in which the surfaces of the mouldings would intersect the surface of the wall, will be equal and similar to the section of the mouldings on the face or intermediate parts between the returns.

In all insulated buildings, where cornices are employed, they should be carried round the entire edifices; unless, in so doing, it is thought too expensive. But strings, and other collections of horizontal mouldings, are frequently interrupted, even in the lengths of the fronts, by certain vertical projectures which are more prominent.

Horizontal mouldings, placed over the architraves of apertures, and projecting over the extreme parts of the architraves where they terminate on the walls, or over the superior terminating members of the fronts of those architraves, are called the *cornices* of the windows or doors over which they are introduced. And if the architraves be joined to such cornices, the entire are called *architrave cornices, or imperfect entablatures.*

Any face of a projection, which is parallel to the surface of the wall, is termed the *front* of that projection.

When any projection exhibits three vertical faces; the middle one, being parallel to the surface of the wall, and the other two perpendicular to it, the two faces which adjoin the wall are called *flanks.* Hence the three faces exhibited are the front and the two flanks.

Here it will be necessary to observe that, when the lengths, breadths, and heights of projections are mentioned, the lengths are measured in horizontal lines parallel to the naked faces of the walls from which they protrude; and the breadths are measured parallel to those faces; consequently the breadths, in the proper sense, is the same as the projecture. Hence we perceive that the greatest extension of a body is not always its length.

When a projection, exhibiting a face and two flanks, is placed between the cornice and the architrave of an aperture, so that each flank may be in the same plane with each side of the architrave, which terminates against the wall, the projection thus described is called a ***Frieze.***

The cornice, frieze, and architrave, are collectively termed the *entablature* of the door, window, or other aperture, to which they belong.

In this enumeration we include only the horizontal part of the architrave, and not the vertical mouldings belonging to it.

In buildings, upon magnificent scales, projections, similar to the entablatures just described, are carried round the edifices; and where the expenses are limited, along the front only, these projections are also termed ***Entablatures.***

But where entablatures of this latter description are executed, it is usual to introduce other equal and similar projections, exhibiting the fronts and flanks; these terminate immediately under the entablatures at the upper extremities, and upon the horizontal surfaces of projections at their lower extremities. The projections thus terminated are called *pilasters.*

Pilasters generally terminate at the top, with mouldings, which return on the sides adjacent to the wall in the same manner as the fronts, which are parallel to them; the mouldings which thus terminate the upper extremities of the pilasters are called capitals: and very frequently these capitals consist both of mouldings and ornaments.

Occasionally, return mouldings are introduced also at the lower ends of the pilasters; and the mouldings thus situate are called the bases of the pilasters.

The surfaces of pilasters are often ornamented with a series of equal and similar concave mouldings, terminating in vertical edges; mouldings thus introduced are called *Flutes.*

Flutes terminate in different manners at their upper and lower extremities, or where they enter the faces of the pilasters, so as to preserve entire the parts of these faces, whether above or below. But the forms in which they terminate are generally the same as those of their horizontal section, supposing the pilasters to be cut through any intermediate parts of the heights.

In the recess of an internal angle, formed by two planes of a cornice, or even in a string course, a series of equal and similar prismatic solids are sometimes attached to each of those planes, so that every solid may exhibit four entire faces. The solids thus attached are called, according to their forms, *dentils, blocks, mutules, modillions,* or *cantalivers.*

When they are very small and near to one another, so that their heights may exceed their lengths, and also, that the horizontal distances between each and those immediately adjacent may be less than their lengths, they are called *Dentils;* and the cornices are said to be *denticulated.*

If the length of each solid be greater than its height or breadth, the solid is called a *Mutule,* and the cornice itself a *mutule cornice.*

If the distance between each solid exceed twice its length, and if the projecture be from twice to three times the length, each solid is called a *Modillion;* and the cornice thus ornamented a *modillion cornice.*

When the projecture of each solid is more than thrice the length, each solid is called a *Cantaliver;* and the cornice itself a *cantaliver cornice.*

## PROPORTIONS OF MOULDINGS.

When a room is adorned with an entire entablature, its height may be about one-sixth part of the height of the room; or, in some cases, one-seventh. If a cornice only is executed, its height may be about one-

twentieth, or one-thirtieth part of the height of the room; the proportion depending entirely on the combination, number of mouldings introduced, and their purpose or design. Thus, in the houses of middling classes of people, the cornices may be made light; but, in the houses of the nobility, where grandeur is an object, they should have more massive appearances; and it may be laid down, as a general principle, that all interior decorations and proportions of mouldings must be lighter than those employed in the exterior parts of buildings. The reason of this is obvious; for, in a room, where the eye is confined within a certain distance, and the ornamental parts large, they will naturally appear heavy; but, on the exterior of edifices, the mouldings are viewed with reference to the sizes of the entire buildings, which proportionately diminishes their magnitude; and the advantage of seeing the object at different distances, tends still further to lessen the effect of projectures.

## ON THE BEAUTY OF BUILDINGS.

In the arrangements and proportions of the parts of buildings, they ought to be such as to elevate the pleasures of imagination to the sublime, (which is superlatively explained by a great writer,) to bear the features characteristic of its destination. Grandeur cannot exist without magnitude, both in the entire and in its parts; but a building may be great, and the parts massive, without its being grand. Besides magnitude, a considerable degree of elegance is required to produce grandeur. Sameness of surface, without diversities of figure symmetrically disposed, will not raise any pleasure in the mind. But, when the parts of an edifice follow each other alternately, or repeat a series of symmetrical portions in succession, the combination is easily understood, and the imagination pleased with the uniformity and variety of the compositions.

As a cylinder is a pleasing object, since no two parts of its surface, nor of its circular ends, are alike opposed to the eye; so, in executing a circular building, the terminations ought to be in continued circles. Hence the entablature of such an edifice should not, on any account, be broken; though the intermediate parts of the wall may be decorated with well-proportioned symmetrical parts, as columns, pilasters, or ornamented windows; which, if judiciously introduced, cannot fail to produce the most pleasing effects.

Though definite rules cannot be laid down for the formation and contours of buildings, yet the centre parts ought to assume commanding features, and the grand outlines of the entire should, generally speaking, approach to those of the pyramidal forms.

Lodges, and small houses standing alone, show, with good effect, when their figures approach to the forms of cubes: but, in large mansions, rectangular prisms, with oblong bases, have more pleasing appearances than cubes. The proportions of large buildings may be termed good when the lengths do not exceed the breadths, in greater portions than when they are about four to three.

## SITUATIONS FOR COUNTRY RESIDENCES.

The most essential qualities of good situations are those that are most conducive to health. Where persons intending to build, enjoy the power of fixing upon situations, they should sedulously avoid the proximity of marshes, fens, boggy ground, or stagnant water: and, if rivers are very near, the sites of the houses should be on elevated ground, so as to be out of the reach of unwholesome fogs, which rise from the water at particular periods. In neighbourhoods where the inhabitants are healthful, cheerful, and remarkable for longevity, these may be regarded as possessing salubrious air. Easy accesses to public roads, with supplies for water and fuel, are indispensable requisites in the choice of situations.

Again, it is much better to have a house sheltered by trees than by mountain scenery; because the former yield a cooling and refreshing air, which, during the heat of the summer months, is not only pleasing but animating; and, in winter, they serve, in some degree, to break off the keenness of the blasting winds and tempests; while mountains, according to their position, protect only from certain winds; and if the situations are directly east or south, they will be found extremely unpleasant at particular seasons of the year.

And with regard to the positions of apartments, such as studies, libraries, dining and drawing rooms, boudoirs, principal and inferior bed-chambers, dressing-rooms, &c., all these should be arranged according to existing circumstances; taking care, if possible, to place the studies or libraries to the north, and the dining and drawing rooms in such places as to avoid too much of the morning and evening sun: and with regard to the residue, such as kitchens, sculleries, &c. they should be situate so as to prevent the fumes of stews and offensive smells from approaching any of the best apartments, yet, at the same time, be so contiguous as not to create unnecessary trouble to servants, whose comforts should be studied, which, if neglected, the house is sure to be comfortless.